Breeding biology, and egg and larval development of *Galaxias rostratus* Klunzinger, the Murray Jollytail from inland New South Wales

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ABSTRACT

G. rostratus the Murray Jollytail bred in earthen ponds at the Inland Fisheries Research Station, Narrandera, NSW, when surface and bottom water temperatures were above 10.5°C during August and September. Flooding was unnecessary but there was water flow through the pond. Eggs were demersal, transparent, spherical, telolecithal and slightly adhesive; possessed a cluster of oil globules; varied from 1.35mm to 1.66mm in diameter; and appeared to be scattered randomly on the pond bottom during spawning. Eggs hatched after 8½ to 9½ days. The length of recently-hatched larvae ranged from 5.7mm to 8.1mm. The pro-larval stage terminated at around 5days after hatching. Water temperatures varied between 13.8 and 20.0°C during development. The largest adults collected were 15.0cm and weighed 22.5gm. Marked colour differences between the sexes were not obvious, but sex could be determined by the appearance of gonads through the transparent window anterior to the vent close to the breeding season. Fecundity of the females varied from 2300 eggs at 86mm body length and 4.7gm body weight to 7000 eggs at 136mm length and 19gm weight. The gonosomatic index rose to 40.0 and 31.2 in females and males respectively prior to breeding. The breeding and larvae of *G. rostratus* are compared to other Australian mainland Galaxiidae, and other freshwater fish larvae of inland NSW.

Key words: *Galaxias rostratus, Galaxias planiceps*, Murray Jollytail, breeding biology, egg and larval development, fish inland NSW.

Introduction

Breeding experiments on inland freshwater fish, particularly small forage species, were carried out at the Inland Fisheries Research Station, Narrandera (currently known as the Narrandera Fisheries Centre) between 1964 and 1973 to assist with identification of eggs and larvae and to determine the environmental conditions associated with their breeding. A better understanding of the environmental cues for breeding of freshwater fish is crucial for their management and conservation. Also, forage fish were seen as an important part of the food chain for the large fishes of economic importance. However government research at the time was directed towards increasing and maintaining stocks of fishes of commercial and recreational value, such as Murray Cod *Maccullochella peelii peelii*, Golden Perch *Macquaria ambigua* and Silver Perch *Bidyanus bidyanus*.

Galaxias rostratus Klunzinger, belongs to the Family Galaxiidae and was previously commonly known as *Galaxias planiceps*. It is one of twenty species in this family that occur in Australia, 50 species occurring worldwide (McDowall and Fulton 1996). Sixteen of the twenty Australian species occur in Tasmania and seven of them occur in SE mainland Australia. *G. rostratus* is the only species occurring in the sections of the Murray, Lachlan and Murrumbidgee Rivers that flow on the inland plains of New South Wales (Plate 1). The distribution of *G. rostratus* overlaps with that of *G. brevipinnis* and *G. maculatus* in the very lower reaches of the Murray River and with *G. olidus* in the upper far eastern reaches of these Rivers.

The known biology of the Australian Galaxiidae is summarised briefly by Koehn and O'Connor (1990). In most species, biological information is very limited, and very little is known about *G. rostratus*. Breeding strategies and time of breeding in the Galaxiidae, where known, vary from March to November. Koehn and O'Connor (1990) summarises well the information available on *G. rostratus* to that time. Information in the review includes: egg numbers for 95mm fish (1028) and 110mm (1888) and egg size 0.56 ± 0.09mm (Hume *et al.* 1983); fish shoal in mid water and occur in still and gently flowing waters, lakes, billabongs and backwaters (McDowall 1980); occurs at depths of 1m, substrate of coarse sand and mud, debris and Phragmites (Cadwallader 1979); occurs in salinities up to 8ppt (Chessman and Williams 1974); and occurs in moderately salty lakes (Chessman 1971).

A brief comment on a small portion of this work was published in Llewellyn (1971) when summarising breeding knowledge of inland forage fish; a full account is given here.

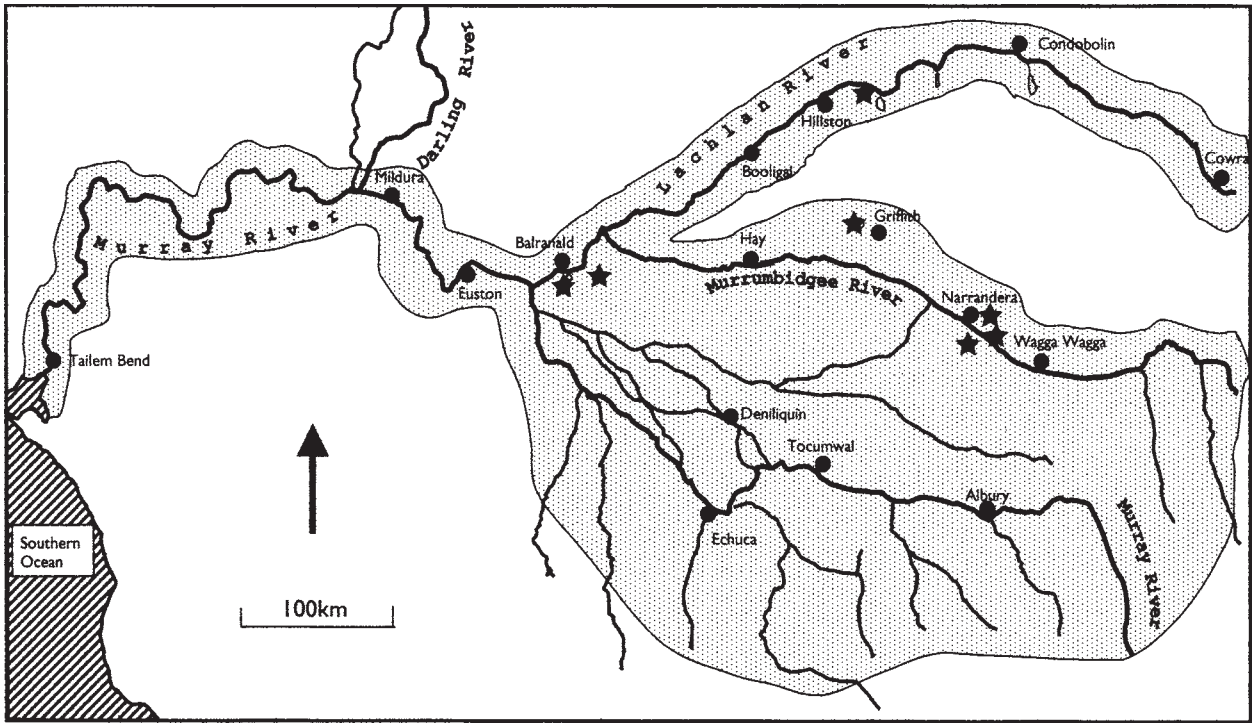

Plate 1. Distribution of *G. rostratus* in the Murray, Murrumbidgee and Lachlan Rivers based on current known, historical and museum records (stippled), and the locations where fish were collected for this study (★). Town locations are marked ● .

Methods

Sampling sites

Because of the difficulty and unpredictability of collecting *G. rostratus*, a planned method and strategy for collecting was not possible. Collections in general were made opportunistically during other sampling programs using beam net, haul net, electro shocking and bait traps baited with bread. When fish were caught, a major emphasis was placed on acquiring live fish for breeding experiments. Sampling sites are given in Table 1 and Plate 1. Willow Dam, approximately 23km NW of Griffith, was a site that was sampled frequently, but somewhat irregularly, and turned out to be the site where most fish were caught. Willow Dam flows over a weir into Barren Box Swamp, a large area that was dominated at the time by Cumbungi, *Typha* spp. On such visits to this site, sampling was carried out over a 6 hour period using a beam push net in riffle areas in the ports below the low level weirs and a haul net in adjacent downstream weedy areas. The sampling method used was efficient and effective allowing most fish within the vicinity of the weir to be caught. Methods of sampling, details of the site, transportation of the fish and other details have been outlined previously (Llewellyn 1974).

A second site, Bartley's Dam, is a small farm dam, which lies in the flood plain of Poison Water Hole Creek, 3km south of the Inland Fisheries Research Station on the Gap Road at Narrandera (Lat.34°48'S Long. 146°32'E). It floods on average every other year and remains totally isolated for most of the time. In June 1970, haul netting was carried out in the dam (Table 1). At the time we were collecting *Carassius auratus* Goldfish (Carp) as bait. Several hauls recovered no carp but a fish was seen to jump the head rope of the net. Six additional hauls were made and fish were again seen to jump the head rope of the net on a number of occasions but none could be caught. An attempt was then made to catch some using bait traps with bread as bait. Within ten minutes two very large *G. rostratus*, (12cm in length) had been caught. Water clarity in the dam at the time was little more than 1cm.

The only other major collections were from a regulator and swamp outlet locality near Balranald on 24 November 1968 (Table 1). Again they were schooling, against a barrier in the water channel, during early summer. It was not possible to return these fish to Narrandera for breeding stock so they were taken for later gonad examination and length frequency assessment.

The dates and locations of all collections at a total of nine different sites were recorded. Usually only small numbers of fish which died during collection and transport, if any, were used for dissection and gonad examination. These limited data allowed assessment of the approximate time of the year of the breeding period of this species.

Inland Fisheries Research Station

All live fish were placed in small ponds 0.01ha in area, which could be filled and emptied through a screened penstock, and had a raceway in the bottom for collecting fish when the pond was emptied. Water could flow through the pond continually if required while being maintained at a constant level. A record was kept of all fish stocked, removed, found dead and any manipulation of the pond carried out; and water temperatures were taken on most week days.

Table 1. *Galaxias rostratus* collected in the Murray Darling between 1966 and 1971.

Date	Location	Lat. / Long.	Number	Method captured	Temperature (°C)	Comment
21.x.66	*Willow Dam, Barren Box Swamp	34°06'S 145°46E	1	Beam and haul net**	18.4	-
7.xi.66	„	„	8	Beam and haul net	-	-
2.xi.67	„	„	227	Beam and haul net	21.7-24.4	Redfin abundant
23.xi.67	„	„	187	Beam and haul net	20.6- 22.8	Redfin abundant
12.xii.67	„	„	154	Beam and haul net	21.2-24.0	Redfin abundant
26.xii.67	„	„	62	Beam and haul net	-	Redfin present
18.i.68	„	„	32	Beam and haul net	22.0-28.0	-
30.x.68	„	„	7	Beam and haul net	-	-
24.xi.68	Regulator, Yanga Lake, Balranald	34°42'S 143°36'E	127	Haul net	-	L=32.6-60.2. Mn 43.5
24.xi.68	Swamp outlet to river 5km NE Balranald	34°34'S 143°35'E	62	Haul net	-	L=35.6-56.2 Mn 45.0
22.xi.69	Lagoon, Town Common, Balranald	34°38'S 143°32'E	14	Haul net	-	-
30.v.67	Lake Talbot, Narrandera, Main Canal	34°45'S 146°35'E	1	Electric shocker boat	-	Cyst parasites
7.vi.71	Lagoon, Town Common, Narrandera	34°46'S 146°34'E	20	Haul net	-	-
8.vi.70	Bartley's Dam, Poison Water Hole Creek	34°48'S 146°32'E	5	Bait Trap	-	-
18.vi.70	„	„	13	Bait Trap	-	-
24.vi.70	„	„	3	Bait Trap	-	-
29.vi.70	„	„	5	Bait trap	-	-
2.vii.70	„	„	1	Bait trap	-	-
29.x.72	Lake Brewster (Ballyrogan)	33°24'S 145°59'E	2	Haul Net	-	-
9.4.70	Poison Water Hole Creek, Wagga Road	34°49'S 146°35'	1	Haul Net	-	-

*Nil fish were caught during sampling using the same method and effort at this site on 14.iii.65, 23.iii.65, 14.iii.66, 12.iv.66, 18.x.66, 25.x.66, 1.xi.66, 28.ii.67, 7.iii.67, 3.v.67, 25.v.67, 27.vii.67, 4.ix.67, 18.ix.67, 24.ix.67, 16.xii.67, 14.ii.68, 19.ii.68, 30.iv 68, 4.vi.68, 20.vi.68, 30.vi.68, 17.ii.70

**See Llewellyn, 1974 for further details.

L = Length of fish, Mn = mean length of those indicated in the number column.

Breeding

Irregular samples taken from the wild and occasional fish caught from ponds were used to track the onset of the breeding season. In the ponds, fish were caught with the least disturbance to the pond and fish as possible, either by using a small drag net or, if required, by lowering the water to the level of the raceway to examine the fish. Bait traps proved unsuccessful in ponds on the research station where water was fairly clear. All specimens were measured and weighed (if entire), external characters recorded, and dissected to determine the state of their gonads. Any food in the gut was recorded. If gonads were of sufficient size and were easily recognisable, they were weighed and measured and a Gonosomatic index (GSI) (GSI=(Weight of gonad x100)/Weight of body (Mackay 1973; Belsare 1962)) was determined. The term "gravid" will be used to denote a noticeably distended abdomen resulting from development of the gonads (see Fig. 8c and Table 3 in Results section). When gonad development indicated that spawning may be imminent, regular sampling of the ponds using a plankton net and a small bottom scoop net were used to collect eggs.

When samples of fish could not be used for breeding and the numbers of fish in a sample were large enough, length frequency plots were compiled. The dates at which these samples were taken were used to give an indication of the annual growth rate.

All available temperatures taken were collated and plotted to determine the temperature at which the fish bred. From this information a picture of the breeding cycle could be pieced together and some idea of the conditions required for induction of breeding could be determined.

Once ova or larvae were collected they were placed in separate petri dishes in the laboratory, marked with the time of collection. Their development was recorded at intervals from this time by means of a photograph taken through a Reichert binocular microscope, or through a Wild M20 microscope using Phase Contrast microscopy. The time each photograph was taken, its magnification and any other salient features were recorded. Regular measurements of eggs and larvae were taken using a calibrated micrometer eyepiece. Temperature was monitored at intervals. Using

this information, the development of eggs and larvae was described. Developmental features such as the swelling of ova during water hardening, decline in yolk size, and the growth of larvae were plotted.

The period of development from endogenous to exogenous feeding is critical and often results in high mortality. Attempts were made to provide some alternative food such as fine plankton from ponds at this stage of development, in an attempt to promote larval survival so that their development could be followed.

The breeding and development of G. *rostratus* was compared with some other species of the family Galaxiidae in SE Australia, and egg and larval stages were compared with some other fish species occurring in the Murray Darling.

Results

Sampling strategy and times

The complete record of G. *rostratus* collected by the author in the Murray-Darling in New South Wales giving date, location, Latitude and Longitude, number of specimens collected, method captured, temperature of water and other comments is shown in Table 1. Fish were successfully captured by beam net, haul net, electro shocking and traps baited with bread.

During frequent sampling throughout inland areas of New South Wales, G. *rostratus* was rarely collected and when individuals were caught, they were generally small, no longer than 5 cm in length. They were usually caught in small bodies of water using haul nets. Regular sampling at Willow Dam, Barrenbox Swamp (Lat. 34°06'S, Long. 145°46'E) using a beam net, which fitted the overflow ports (see Llewellyn, 1974), was the only site with relatively large numbers of this species in November and December 1967 (Table 1). The first, single fish of this species was caught on 21 October 1966 and a further eight individuals, seventeen days later. Between 1 and 227 G. *rostratus* were collected at this location over a 6hr period between 10.00 and 16.00hrs. This site was visited frequently but at somewhat irregular intervals on 31 occasions, between 14 March 65 and 17 February 70 (see Table 1 and Fig 1). On only eight of these occasions were specimens of G. *rostratus* caught, with mean number caught per visit in each calendar month varying from 0 to 84.4 (Table 2). They were collected only in late October, November, December and early January suggesting a propensity for up stream movement towards the overflowing water of the weir during late spring and summer. No fish were caught outside this time even though flows over the weir occurred regularly. Water temperatures varied between 7 and 28°C during visits between 1965 and 1970. The frequencies of visit, temperature and times of fish capture between late 1966 and early 1968 are shown in Fig. 1. Fish were only caught on rising water temperatures when they were above 20°C during late spring early summer.

In June 1970 a total of 27 large G. *rostratus* around 12 cm in length were collected from Bartley's Dam over 3½ weeks, using bait traps (Table 1); while haul netting had failed to catch any fish. These fish were used as the basis of further breeding trials. At the time, the fish appeared to be gravid with distended abdomens and it seemed that breeding was imminent, which agreed with observations from the previous two years. Consequently they were placed in a small pond at the Inland Fisheries Research Station. These fish bred shortly after stocking and provided the majority of the data for this report on breeding biology and egg and larval development.

The only other major collections were the 127 and 62 taken by haul net at the Yanga Lake regulator and Swamp outlet respectively at Balranald on 24 November 1968 (Table 1). They were schooling against a barrier in the water channel. They were not used as breeding stock.

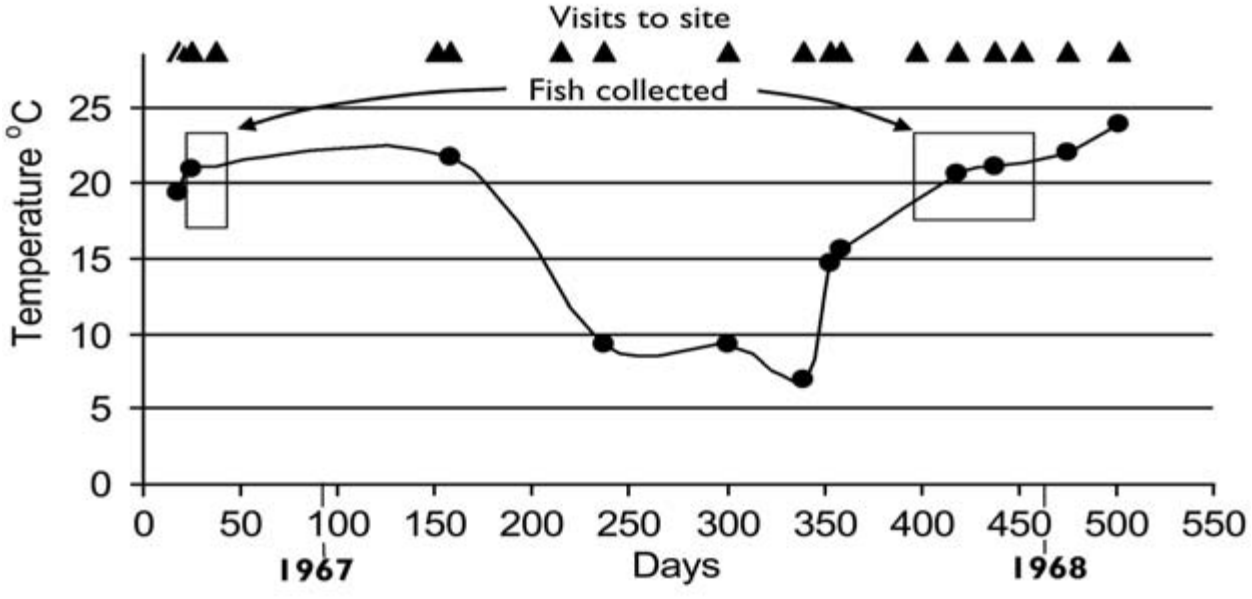

Figure 1. Water temperatures recorded during visits to Willow Dam ●——● and periods during the year when *Galaxias rostratus* were caught delineated by boxes (see Table 1). ▲ Times at which the site was visited and sampling was carried out. Day 0 = 1 October 1966.

Table 2. Willow Dam - catches of *Galaxias rostratus* and number of visits in each calendar month from 14 March 1965 to 17 February 1970.

Month	J	F	M	A	M	J	J	A	S	O	N	D	Total
No. visits	1	4	3	2	2	3	1	-	3	4	5	3	31
No. of visits fish caught	1	0	0	0	0	0	0	-	0	2	3	2	8
No. of fish caught	32	0	0	0	0	0	0	-	0	8	422	216	678
Mean No. of fish caught per visit	32	0	0	0	0	0	0	-	0	2	84.4	72.0	21.9

Breeding trials in aquaria

A large number of *G. rostratus* taken at Willow Dam in November and December 1967, when bottom water temperatures at the site were between 21 and 22°C, were the basis of the first breeding trials. Attempts were made to keep the first fish obtained in 1966 and early 1967 in 90L aquaria where it was easier to observe their development and breeding. Between two and twenty fish were placed in each aquaria and they were fed on small shrimp, zooplankton and phytoplankton. In all cases, fish lost condition and died over a period of a month. Difficulties in maintaining or building up fish condition were also experienced when attempting to breed Pigmy Perch *Nannoperca australis australis* and Freshwater Hardyhead *Craterocephalus fluviatilis* in aquaria (Llewellyn 1971, 1974, 1979). It seemed likely that inadequate food was being supplied and unless the condition of fish could be improved, spawning was unlikely to occur in aquaria.

Breeding trials in open ponds

Since fish numbers were limited, further attempts to induce spawning were restricted to small ponds 0.01ha in area and 137-183cm deep. For most of the time a slow flow of water was maintained through the ponds. Survival in ponds was variable, sometimes poor, significant numbers vanishing for no apparent reason, although predation by cormorants was suspected. Breeding success is summarised in Table 3.

Of the fish caught at Willow Dam in November, December and early January 1967-68 (Table 1), 500 were placed in one pond and 100 in another (all <64mm in length). Their gonads at the time were very small and difficult to find. Samples of these fish taken from the ponds between January and June 1968 showed a progressive increase in GSI and a noticeable extension of the abdomen in some fish indicating that the breeding season was approaching. Of nine fish caught in the pond by haul net on 23 July 68, four were males running ripe, and one was a female which had not spawned, but ova were loose in the body cavity. These ova could not be stripped. All fish were immediately returned to the pond. Water temperature at the time was 10.3°C. From this time, benthic and plankton samples were taken every second day. Two eggs were collected from one pond in benthic samples on 20 August 68 when water temperatures were 10.6°C and water was flowing gently through the pond (Table 3). The eggs hatched 3 days later. A number of larvae were found in material from plankton tows. Six hundred and thirty three young and 18 adult fish were recovered from the pond on 23 December 1968. Surface and bottom pond water temperatures (Fig. 2) indicated that temperatures fluctuated between 6.0 and 12.0°C between mid May and end of August but spawning occurred when both bottom and surface temperatures rose above 10.5°C on 20 August 1968.

Fish from the 1968 season were maintained in the ponds over the 1969 season. On 15 August 1969, while sampling for eggs, the skeleton of a fish was found. Examination of a live adult indicated they were very gravid and about to breed. As no eggs were collected on the following days, an attempt to capture an adult was made on 25 August 1969. Four hauls produced no fish so the pond was lowered to the raceway. Only one live fish was caught and five partially decomposed bodies were found (see Table 3). The reason for mortalities could not be determined.

Between 8 June and 2 July 1970, 27 mature, gravid *G. rostratus* were captured in bait traps in Bartley's Dam close to the Research Station (Table 1). Twenty three were put into a pond and benthic samples were taken daily from mid July onwards. The first egg was collected on 27 August 1970 when pond temperatures were 10.8°C and eggs were collected daily until 1 September 1970. Larvae were also collected on 27 August 1970 suggesting that the first spawning had occurred about the 15 August 1970. Subsequently, a single egg was collected on 6 October 1970 when water temperatures were 15.8°C. Repeated efforts to collect additional eggs were unsuccessful. When the pond was finally emptied in mid August 1972 no *G. rostratus* were present.

Table 3. Time of stocking, size of fish and breeding success of *Galaxias rostratus* in ponds at the Inland Fisheries Research Station, Narrandera, NSW from 1967 to 1972.

Stocking of ponds	Pre-breeding observations	First eggs found	Temperature	Comments
November 1967 to January 1968 fish< 64mm	Gravid 23/7/68	20/8/68	10.6°C	Water flowing through pond
Maintained with fish for 1969	15/8/69 fish very gravid	25/8/69 no eggs, 1 live fish and 5 corpses found in pond	-	Water flow maintained
Stocked June/July 1970, fish>80mm	Fish gravid from July onwards	Eggs collected from 27/8-1/9/70 and 6/10/70	10.8°C 15.8°C	No fish in pond in August 1972.

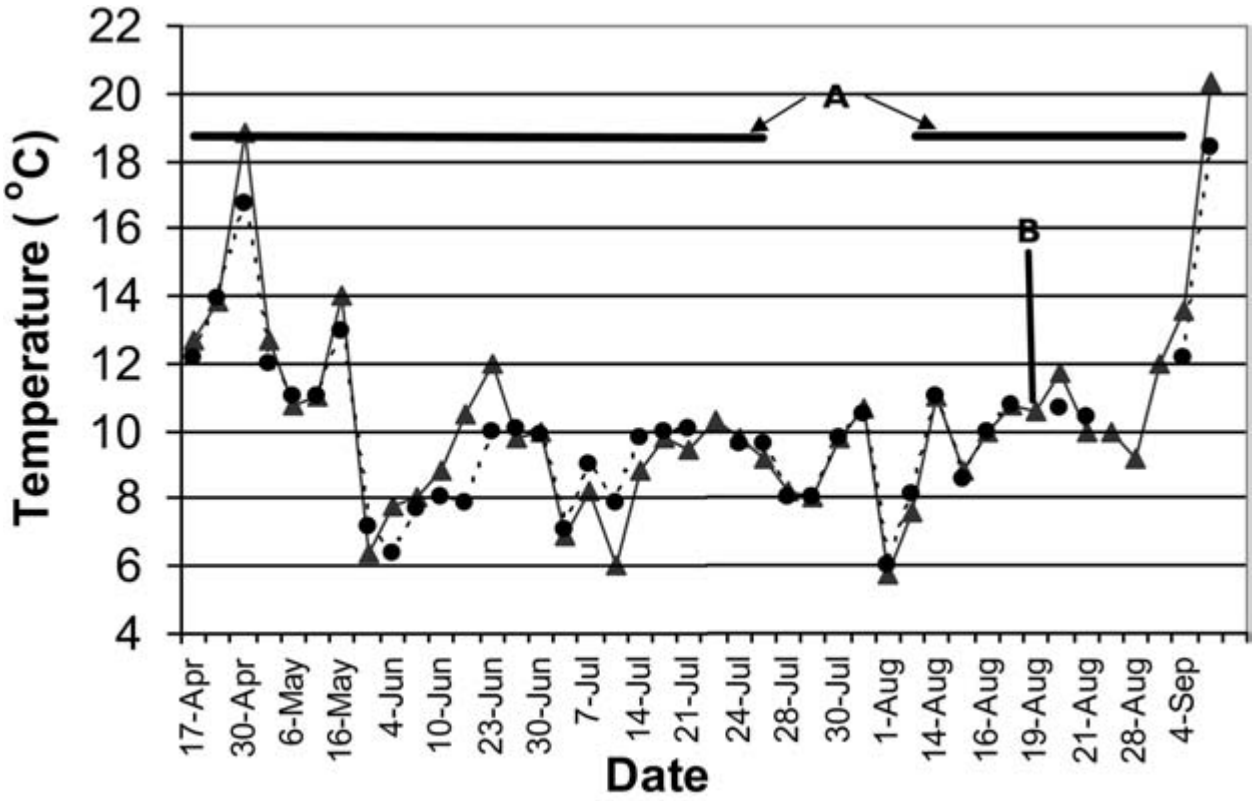

Figure 2. Surface temperature (▲——▲) and bottom temperature (●– – – – – –●) in breeding pond from April to October 1968. "A" heavy solid line represents time when water constantly flowed through pond, "B" breeding occurred, two eggs found on 19 August 1968, when the water temperature was 10.6°C.

Embryonic Development of Egg

Organogenesis in *G. rostratus* is similar to most other teleosts, as described by Kuntz and Radcliffe (1915), Lagler (1956), Manner (1964) and many others. A detailed description of this species is however necessary because the comparative size, appearance and timing of occurrence of various structures are the only clues to the identity of their egg and larval stages (May and Gasaway 1967).

All eggs were collected from ponds and then kept in petri dishes in the laboratory. In the laboratory, water temperatures varied between 13.8 and 20.0°C during the developmental stages depicted in the following figures**.** However water temperatures in the ponds where eggs were collected varied between 9.2 and 12.0°C when first collected. Normal development occurred at the temperatures within the laboratory, although it is likely that the rate of development and egg mortality was increased at the higher temperatures, as has been shown in other species (Piavis 1961; Lagler *et al.* 1967; Edsal 1970).

The eggs of *G. rostratus* (Fig. 3a and b) are demersal, transparent, spherical and slightly adhesive when

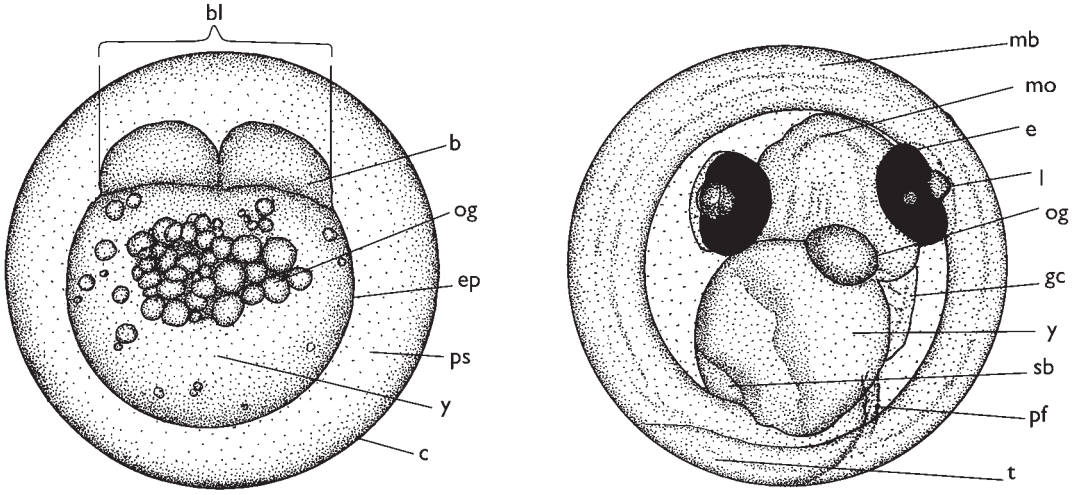

Figure 3 Eggs of *Galaxias rostratus* a) at two cell stage (2hr 22 min old) and b) at 7days 15 hours old. b blastomere; bl blastodisc; c chorion; e eye; ep extraembryonic periblast; l lens; gc gill chamber; mb mid body region; mo mouth opening; og oil globule; pf pectoral fin; ps perivitelline space; sb swim bladder; t caudal fin and y yolk.

spawned. Small fibres and other debris frequently adhere to the chorion particularly when freshly spawned, and in some eggs a few short spike-like processes were observed. At spawning, a layer of mucus surrounds the egg, and the perivitelline space is not readily discernable (Fig. 4a). The mucus soon disappears on contact with water and after fertilisation, as the egg distends during water hardening of the chorion (shell). The perivitelline space forms and increases during this distension (Fig. 4b and Fig.5). Water hardening takes about 15min as the egg increases by over a third from around 1mm to ~1.4mm (Fig.5). Unfertilised eggs continue to distend until they burst.

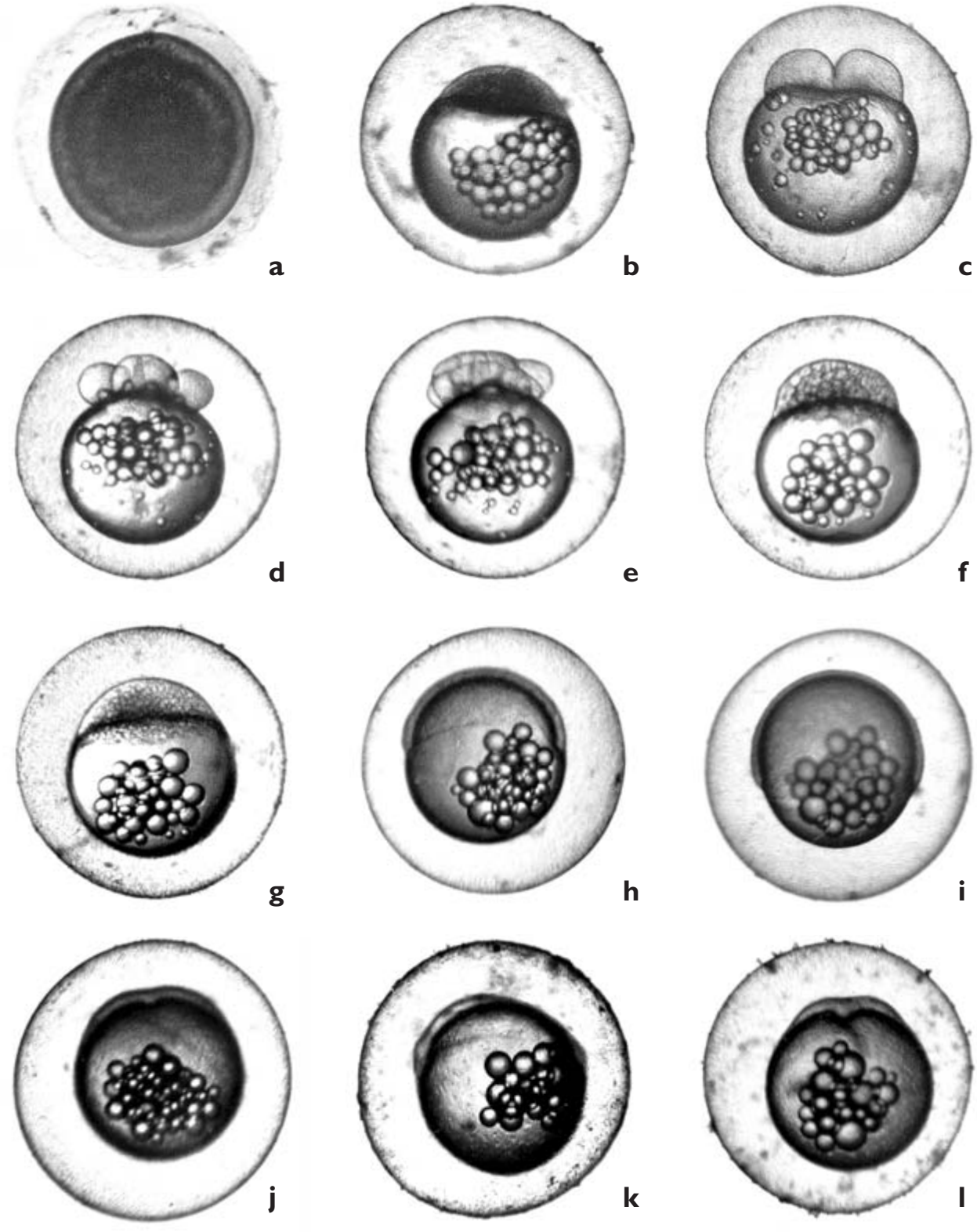

Figure 4. Eggs of *Galaxias rostratus*. Times given are after spawning (d = days, h= hours and m=minutes). a) 10m, b) 1h 45m, c) 2h 22m, d) 3h 55m, e) 4h 46m, f) 8h, g) 9h 55m. h) 19h, i) 22h 4m, j) 1d 7h 10m, k) 1d 9h 10m, l) 1d 11h 20m. Temperature 14-20°C.

At the time of spawning pre-morphogenetic organisation of the ovum is still occurring in teleost eggs (Devillers 1961). Oil progressively coalesces into globules and cytoplasm slowly moves towards the blastodisc during bipolar differentiation, carrying with it numerous oil globules which are dispersed throughout or around the yolk (Fig.4a and b). The egg during this phase changes from a centolecithal to a heavily telolecithal type, which ultimately gives rise to meroblastic or discoidal cleavage (Manner, 1964).

Newly spawned non distended, spherical eggs varied in diameter from 1.02 to 1.11mm (n = 4) with a 0.37mm thick layer of mucus surrounding them. When water hardening of the chorion had ceased, their diameter had increased to 1.35 to 1.66mm (Mn = 1.44mm, n = 58). The yolk nearly equalled the egg diameter prior to distension, since no perivitelline space was present. After distension had occurred, the yolk was generally slightly flattened in one plane. Shortly after spawning, the yolk diameter running through the animal and vegetal pole of the egg varied from 0.67 to 0.74mm (n=3) while the diameter at right angles to this varied from 0.78 to 0.89 mm (n = 6).

The dispersed oil gradually coalesced into larger globules which accumulated centrally (Fig. 4b-e) by the commencement of cell differentiation, 1h 45min after fertilisation (Fig. 4.b). They numbered between 25 and 30 and measured between 0.04 and 0.13mm in diameter. The yolk normally lay centrally within the chorion leaving a perivitelline space right around the yolk between the chorion and yolk, varying between 0.16 and 0.32mm. The fully distended first cell (0.74mm in diameter Fig. 4b) had undergone the first cleavage by 2h 22min (Fig 4c) at 18.0^{0}C in the laboratory. General observations indicated development was slower at lower temperatures. The time between cleavages from the two-to-four celled stage (Fig. 4c-d) and four-to-eight celled stage (Fig. 4d-e) were 1h 30min and 50min respectively and the two and four celled individual blastomeres measured 0.37 and 0.23mm respectively. During these early divisions, the vegetal plain of the blastomeres, where they were in contact with the yolk, showed noticeable intrusions into the blastomere during each division. From this point in development onwards, it was not possible to follow carefully the periodicity of cleavage, but only its general pattern.

The knob of cells (blastoderm) estimated as 32 and 128 cell stage in Fig. 4f and g progressively increased in size measuring 0.59 and 0.84mm across respectively. At around 10h after fertilisation the individual cells could no longer be seen at the magnification used (x 20), and the knob started to flatten (Fig. 4g) before it commenced to spread over the yolk at epiboly. The blastoderm (0.06mm thick) half covered the yolk at 19h after fertilisation (Fig. 4h) and continued to move down the yolk (Fig. 4i). A thickening of the germ ring forming the embryonic shield appeared by the time the yolk was 2/3rd covered by blastoderm (Fig. 4j) at around 1d 7h. Soon after, the thickening of the neural tube area occurred,

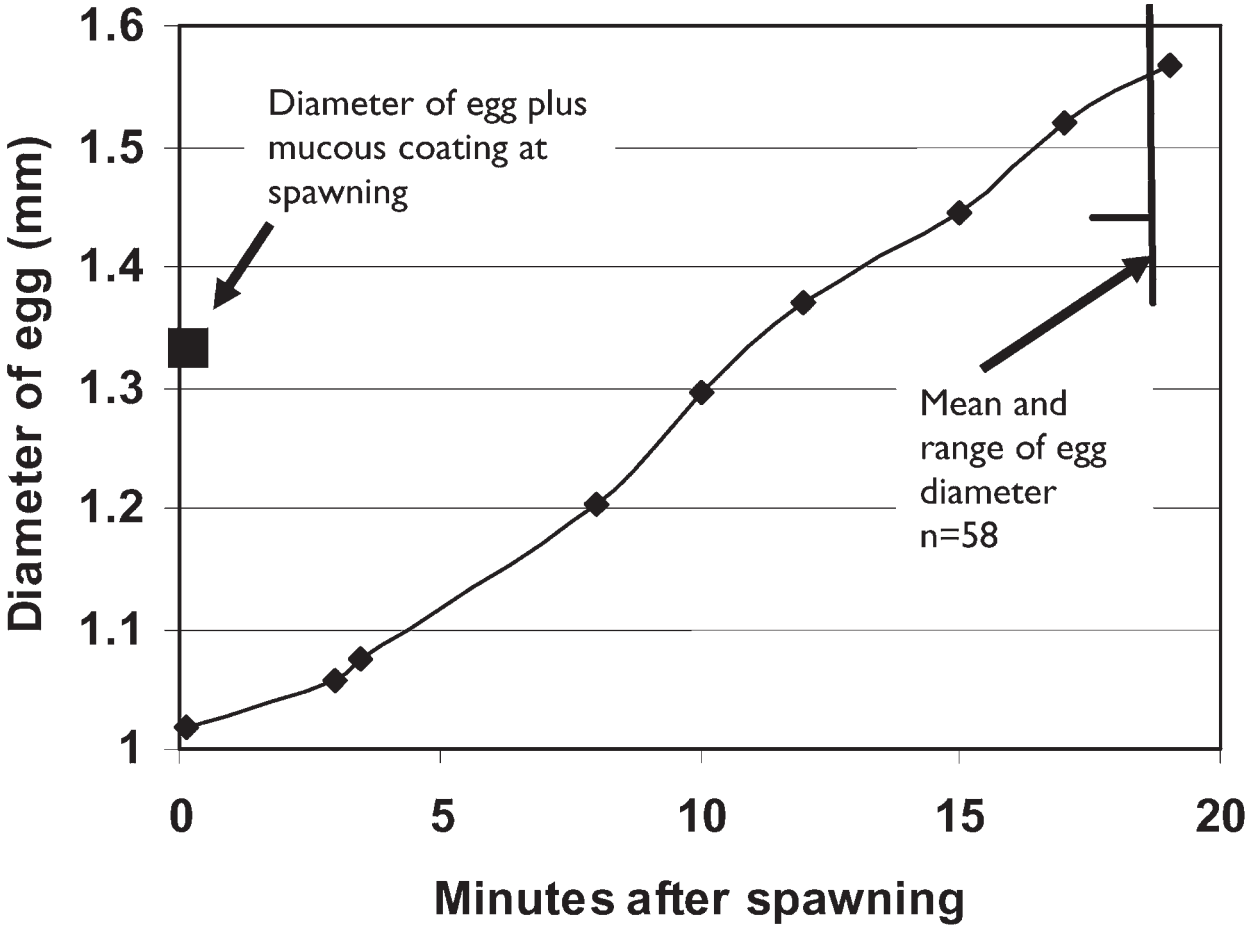

Figure 5. Increase in egg diameter of a typical *G. rostratus* egg during water hardening. The mean size and range of sizes of fully water hardened eggs are shown. The diameter including thickness of mucous coat at spawning is also shown.

accompanied by the commencement of neurulation (Fig. 4k and l). Epiboly continued, eventually forming a yolk plug at around 1d 10h when the yolk was nearly covered by the blastoderm. Blastopore closure occurred soon after this when gastrulation terminated. The embryo showed little visible tissue differentiation up to 1d 15h after fertilisation and lay half way around the yolk (Fig. 6a).

Between 1d 15h and 1d 23h differentiation of tissues into various embryonic structures started to appear (Fig. 6b and c), and the cephalic region enlarged and the optic vesicles (0.13 x 0.24mm) could be seen for the first time (1d 23h). The embryo, around 1.90mm in length at 2½days with a head width of 0.50mm was curled approximately half way around the yolk (Fig. 6d and e). Remaining oil globules coalesced further at this time, often resulting in a single large oil globule (Fig. 6e) reaching 0.38mm in diameter. The sub-cephalic folds, which separate the tail and the head of the embryo from the yolk, were evident

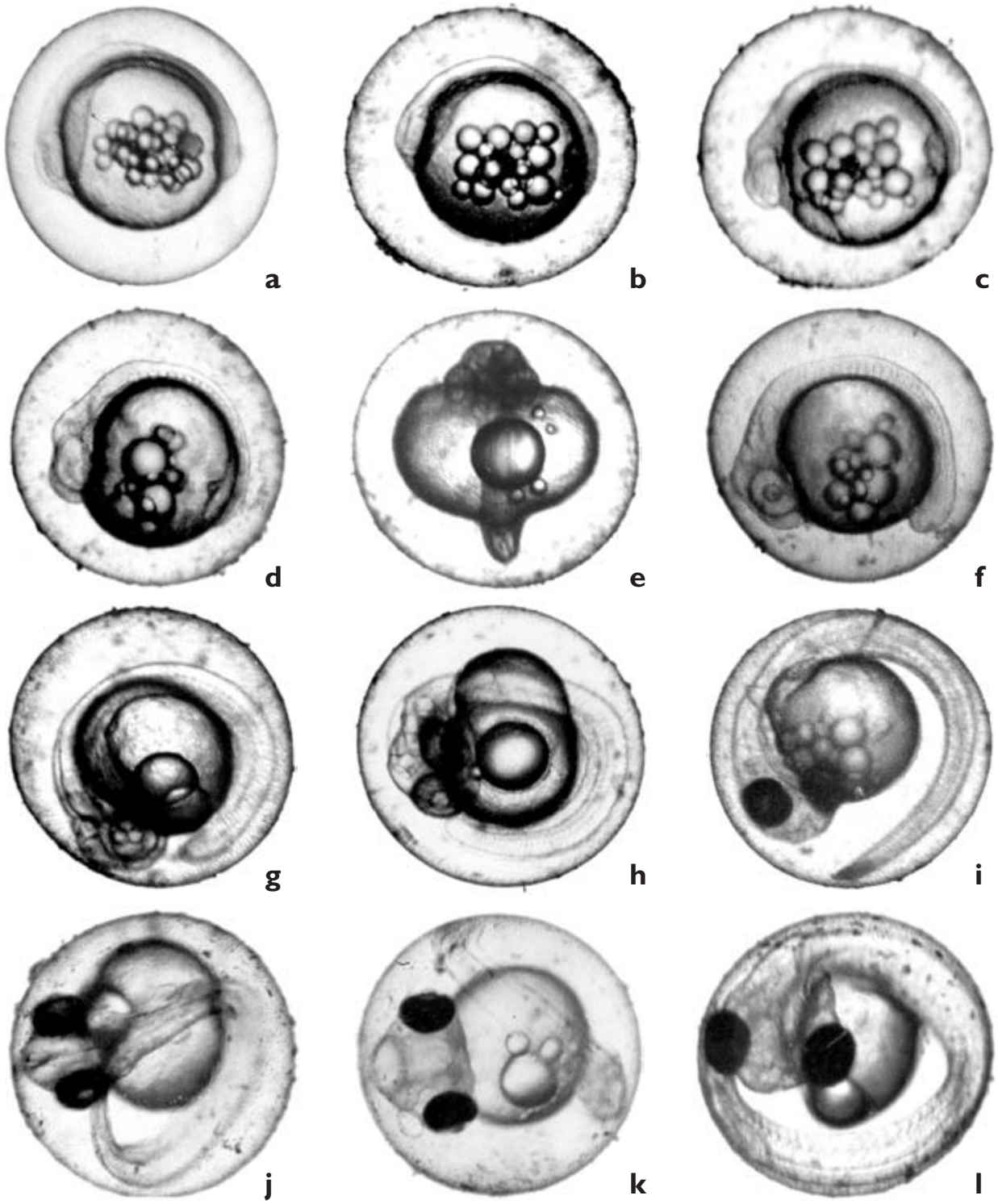

Figure 6. Eggs of *Galaxias rostratus*. Times given are after spawning (d = days, h= hours and m=minutes). a) 1d 14h 50m, b) 1d 16h 10m, c) 1d 22h 57m, d) 2d 7h 29m, e) 2d 19h, f) 2d 22h 40m, g) 3d 13h 31m, h) 4d 8h 40m, i) 4d 19h 30m, j) 5d 10h 10m, k) 5d 21h 20m, l) 5d 0h 22m.

at about day 3 after fertilisation, when the embryo nearly encircled the yolk (Fig. 6f and g). The eye lens in the optic capsule first appeared at 2d 22h (Fig. 6f) and the eye started to become pigmented at around 4d 8h (Fig. 6h). During this period the head increased notably in width and the yolk diameter decreased. By 4½d after fertilisation, the eyes of most of the embryos were fully pigmented. The pericardial cavity was first seen at 4d 19h (Fig. 6i and j), when somatic divisions, marking the myotomes in the caudal region first appeared and the embryo length was about equal to the circumference of the egg (approx. 4.5mm). The first tail movements also were observed at this time. The head (0.77mm), including large protruding eyes (0.34x0.22mm) with lenses, reached half the diameter of the egg by 5d 21h (Fig. 6k and l). A few small melanophores also appeared particularly along the ventral edge of the body musculature, and structures within the head, eg jaws, appeared at this time. By 6½d the body reached 1¼ times around the egg (larval length approx. 5.5.mm) (Fig. 7a-c) and the otic capsules (0.29 x 0.18mm) and otoliths (0.05mm) were visible (Fig. 7b). Some movement of the body of the larvae was seen at this time. The yolk continued to shrink (Fig. 7c-f and Fig. 3b) and generally there was only one oil globule remaining, approximately 0.16mm in diameter at 9d after fertilisation, when the pectoral fins appeared. The fin folds were not seen easily but the depth of the mid body excluding fin folds are around 0.52 mm and the myotomal structure of the mid body could be clearly seen (Fig. 7f and g). Melanophores along the ventral edge of the body and

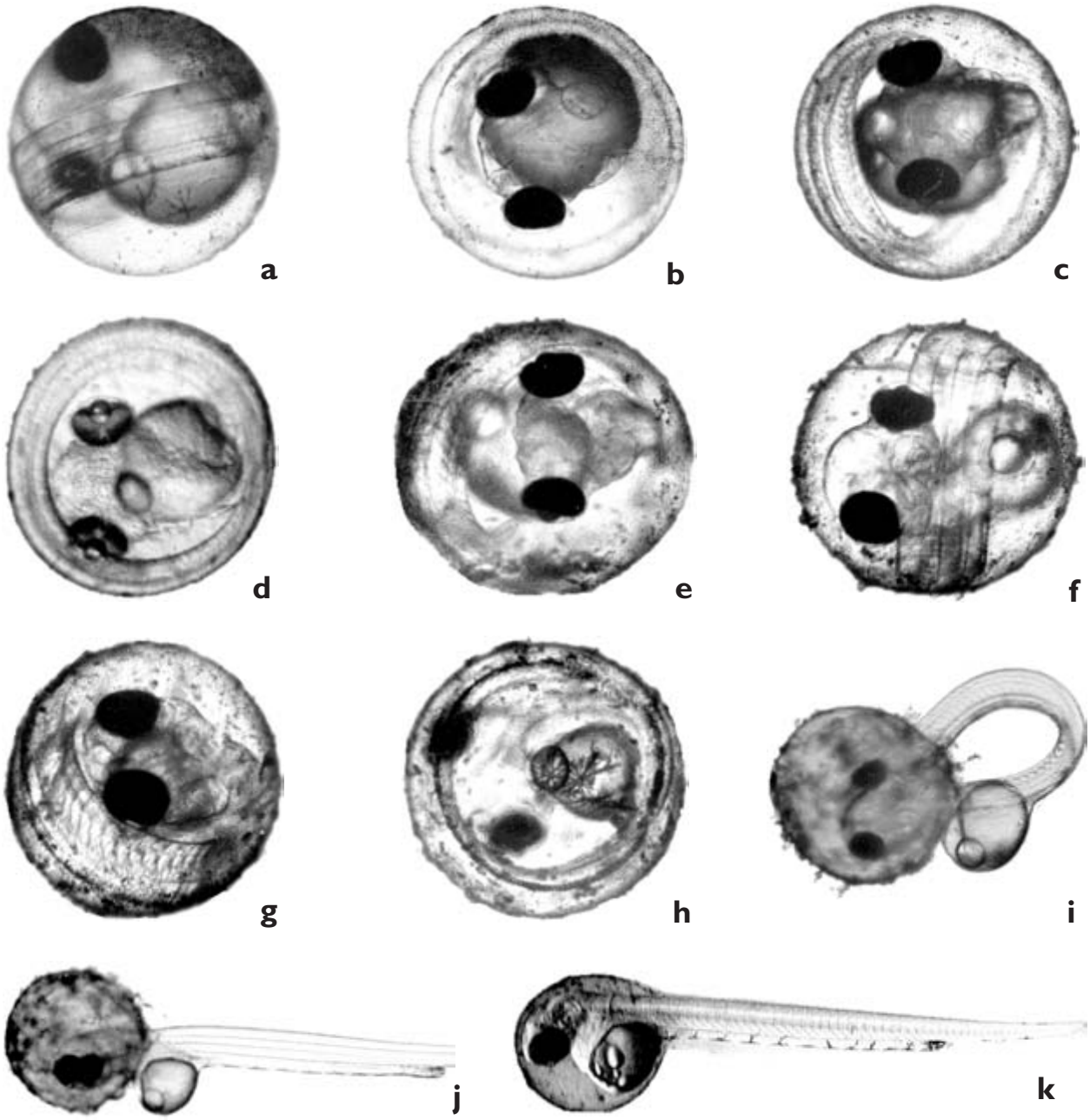

Figure 7. Eggs and larvae of *Galaxias rostratus*. Times given are after spawning (d = days, h= hours and m=minutes). a) 6d 8h 40m, b) 6d 9h 50m, c) 7d 1h, d) 7d 15h, e) 8d 12h 50m, f) 8d 23h 40m, g) 9d 7h 52m, h) 9d 10h, i) 9d 9h 15m, j) 9d 9h 45m, k) 8d 13h 10m.

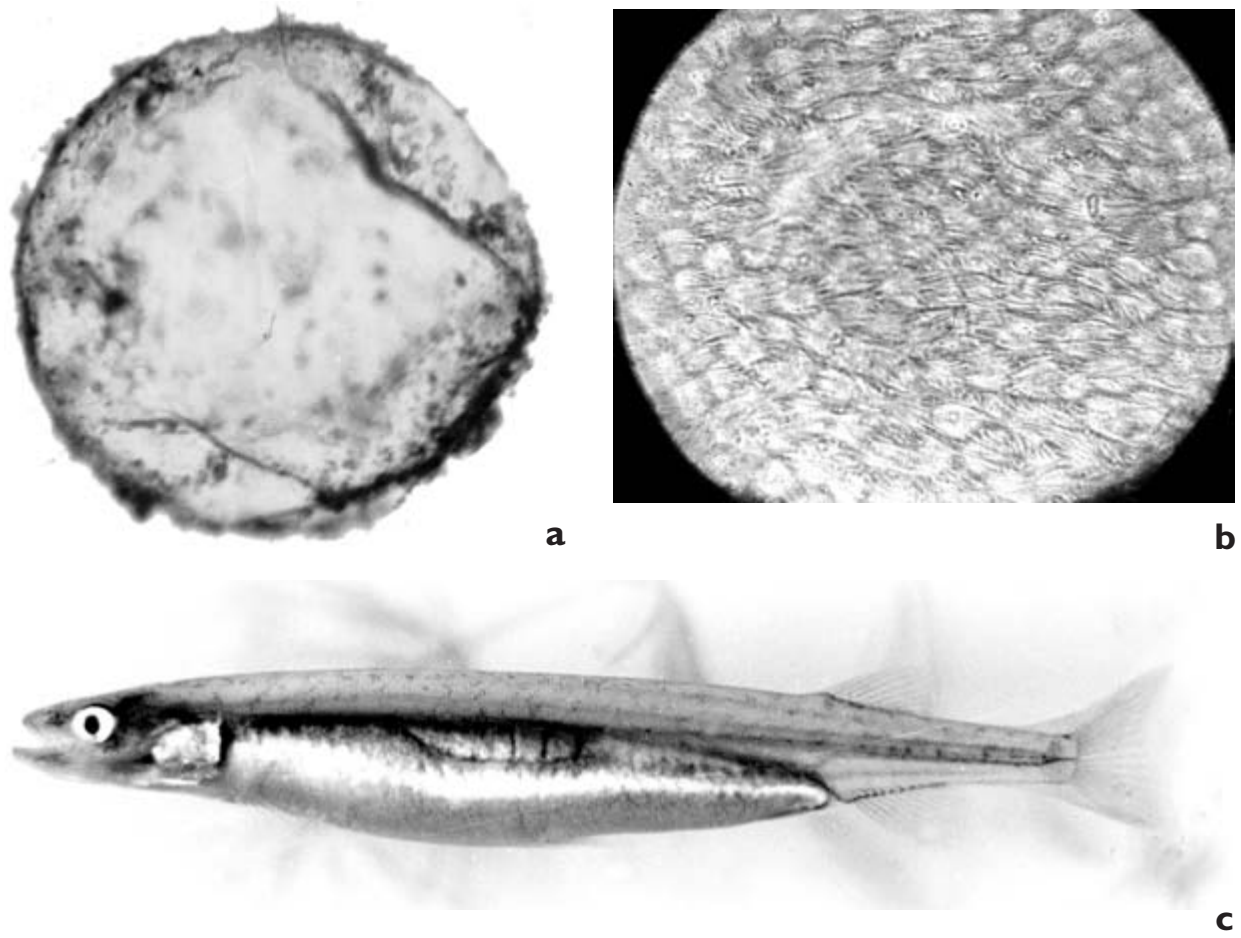

Figure 8. a) Egg shell. b) Tesselated appearance of egg shell (phase contrast). c) Adult gravid female showing distended abdomen.

tail musculature often merged into a continuous line (Fig. 7g) and a few large chromatophores were present dorsally on the yolk at 9d 10h (Fig. 7h). For at least 24 hours prior to hatching, the embryo became quite active within the egg and wriggled or twitched at regular intervals.

The salient features of the embryo just prior to hatching were its length (6.5-8.1mm) which was at least 4.5 times the diameter of the egg, the broad head (0.86mm) over half the diameter of the egg, the large pigmented eyes (0.32mm) and lenses, the small yolk (0.50mm deep), much smaller than its original diameter with generally a single oil globule, and a continual row of melanophores along the ventral edge of the musculature of the tail ending in a dark melanistic patch at the anus lying ¾ of the way along the fish.

As hatching approached, the increased movements of the embryo often caused the whole chorion to flex and distort. The chorion eventually became flaccid, causing the egg to lose its turgidity. Eventually the chorion split and, in most cases, the tail of the larvae emerged first (Fig. 7i, j and k) and the large head was the last to leave the egg shell (Fig. 8a). The surface of the egg shell appeared to be reticulate under phase contrast microscopy (see Fig. 8b) and was about 0.01mm thick. The pro-larvae, as they are known immediately after hatching, continued to thrash with their tail in an effort to free the head end from the chorion. For most larvae, hatched between 8½ and 9½d after fertilisation, the precise stage of development at hatching varied slightly (Fig. 7i, j and k). It should be noted that the hatching time is likely to vary considerably with temperature, as has been demonstrated by Needham (1942) and Konstantinov (1957) for other species.

Development of Prolarva

The terminology used in the subdivision of larval stages is based on the findings of Hubbs (1943), the pro-larva being the term used when the larva still possesses yolk.

The yolk diminished in volume during egg and pro-larval development. The reduction in length and depth of the yolk in the larvae is plotted in Fig. 9. Toetz (1966) measured the reduction in actual volume of the yolk. The exact point which indicates the termination of the pro-larval stage (i.e. the disappearance of the yolk) is difficult to determine because the view of the yolk is sometimes masked by other developing organs.

During pro-larval and early post-larval development temperatures continued to vary between 13.8 and 20.0^{o}C for larvae kept in petri dishes in the laboratory. Just after hatching, the length of the pro-larvae varied from 5.70 to 8.15mm (Mn = 6.84mm, n=21) and the yolk was oval to spherical measuring from 0.63 - 0.74mm in length and approximately 0.50mm in depth. The heart rates of just-hatched pro-larva, were 124-128 beats per minute (n =

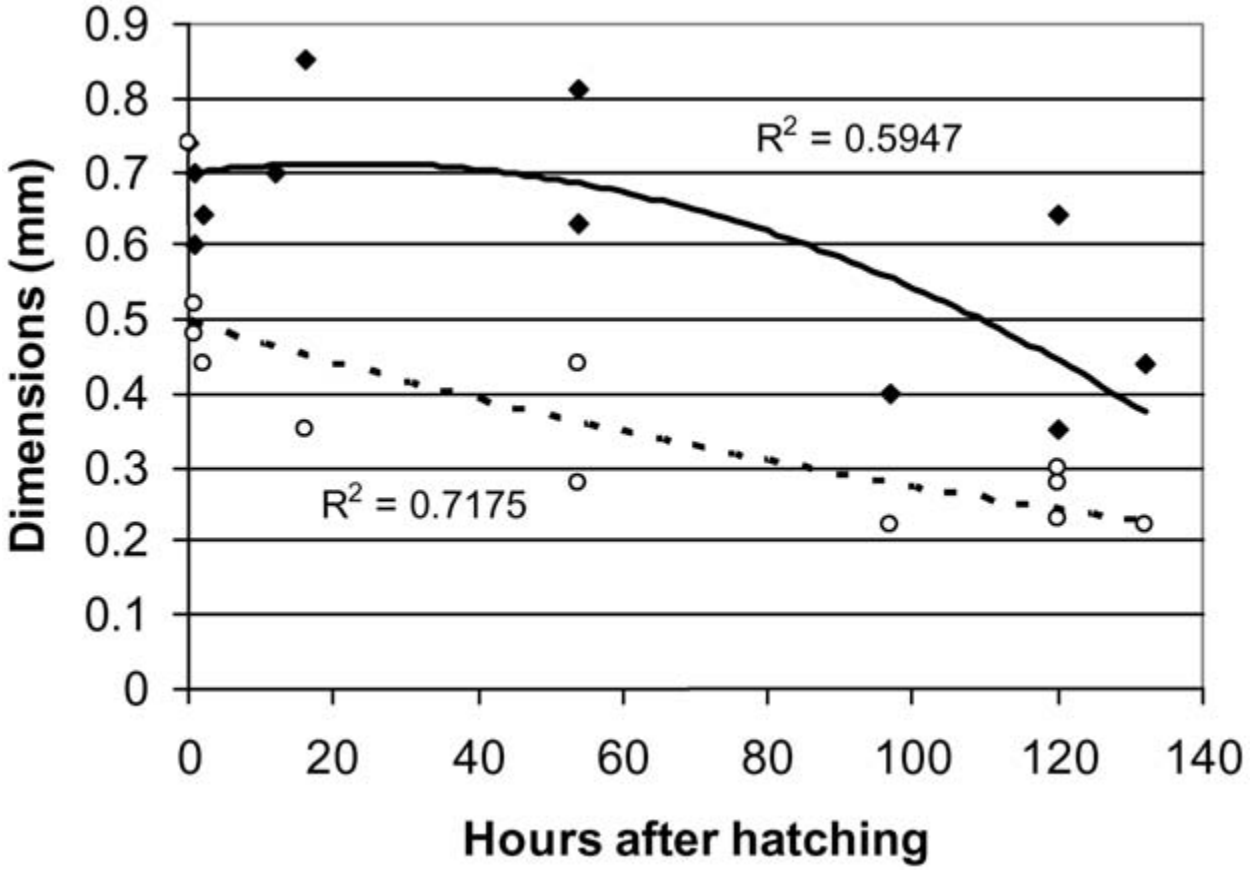

Figure 9. Reduction of yolk after hatching in *Galaxias rostratus*. Reduction in yolk length described by a polynomial curve r^2 =0.5947 (◆——◆), and reduction in yolk depth described by an exponential curve r^2= 0.7175 (O– – – – –O).

3). Activity of pro-larvae just after hatching often made measuring difficult. The general structure of the larva at 2d post hatching is shown in Fig.10.

Because of the variation in length of time to hatching, the developmental stage at hatching varied slightly amongst larvae in the laboratory. Times reported below are times after hatching. In recently hatched larvae the most salient features were the large pigmented eyes (0.29 - 0.33mm), otic capsule (0.29 – 0.37mm), and oil globule (0.24mm), chromatophores ventrally on yolk sac, musculature of tail including myotomal divisions, line of melanophores ventrally along tail musculature (19 clusters) with a large black cluster at anus around ¾ of the way along larvae, dorsal and ventral fin folds (approx. 0.16mm wide) and pectoral fins (0.40mm long) (Fig. 11a,b and c). In a larva of 7.1mm long the fin fold started at 2.76mm from the tip of the snout dorsally, passing around the body and terminating ventrally at the posterior border of the yolk. At about 2h (Fig. 11b and c) the lower jaw could be seen which already possessed small teeth. However, no jaw movements were observed at this stage, and it appeared that they were

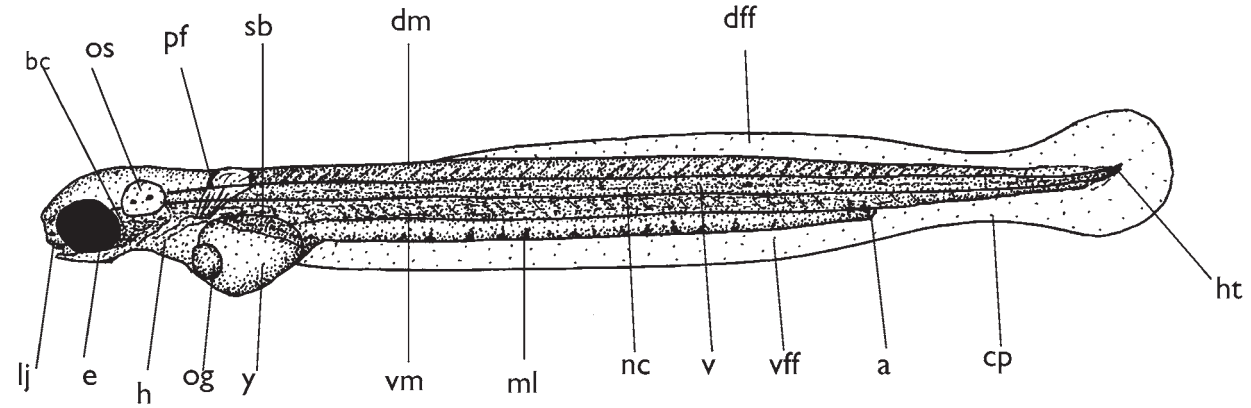

Figure 10. Larva of *Galaxias rostratus* around 2 days old. bc buccal cavity; os otolith sac; pf pectoral fin; sb swim bladder; dm dorsal myotomes; dff dorsal fin fold; lj lower jaw; e eye; h heart; og oil globule; y yolk; vm ventral myotomes; ml melanophores (ventral row); nc spinal chord; v vertebrae; vff ventral fin fold; a anus; cp caudal peduncle; ht heterocercal tail (upturned notochord).

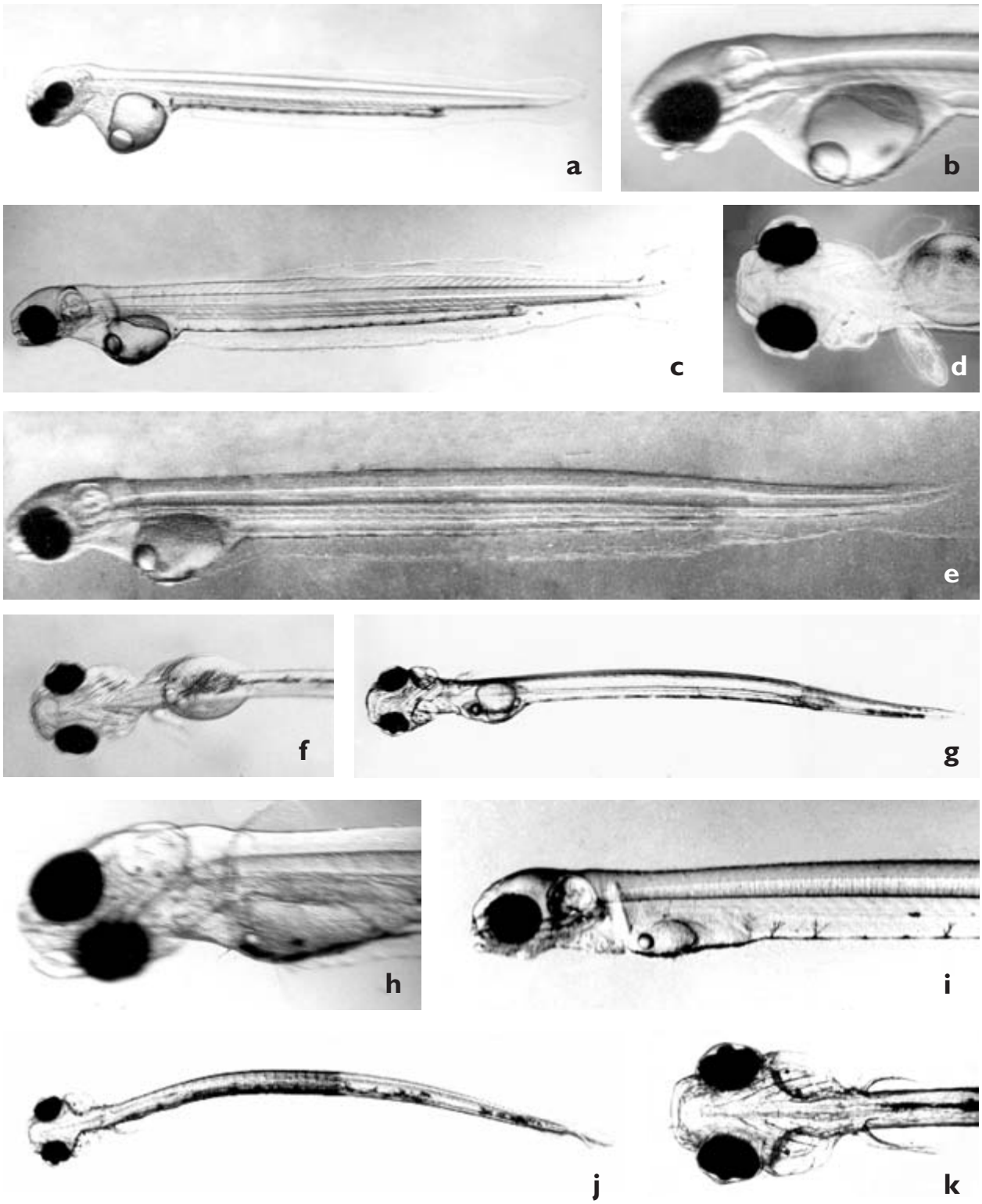

Figure 11. Prolarvae of *Galaxias rostratus*. Times given are after hatching (d = days, h= hours and m=minutes). a) 0m, b) 1h 15m, c) 2h, d) 2h 45m, e) 16h, f) 12h, g) 2d 2h 44m, h) 2d 6h 45m, i) 4d 1h 26m, j) 4d 7h, k) 4d 18h.

not yet able to feed. Yolk was still present. Part of the intestine could be seen dorsal to the yolk at this stage (Fig. 11c) and melanophores became prominent on the ventral side of the yolk. The large pectoral fins (0.42mm in length) could clearly be seen beating at 2h 45min (Fig. 11d) when head width was 0.78mm. The cluster of melanophores ventrally on the yolk, gillrakers and filaments, and other bony structures of the head could be seen at 12h (Fig. 11f). The progressive reduction in size of the yolk sac was obvious between 16h and 2d 6h (Fig. 11e, g and h) with noticeable flattening of the yolk occurring at 2d 6h (Fig. 11h), resulting in streamlining of the body. Between 4 and 5d (Fig. 11i-k and 12a), the yolk virtually disappeared, indicating the approach of the end of the prolarval stage. A single small oil globule remained (Fig. 12a).

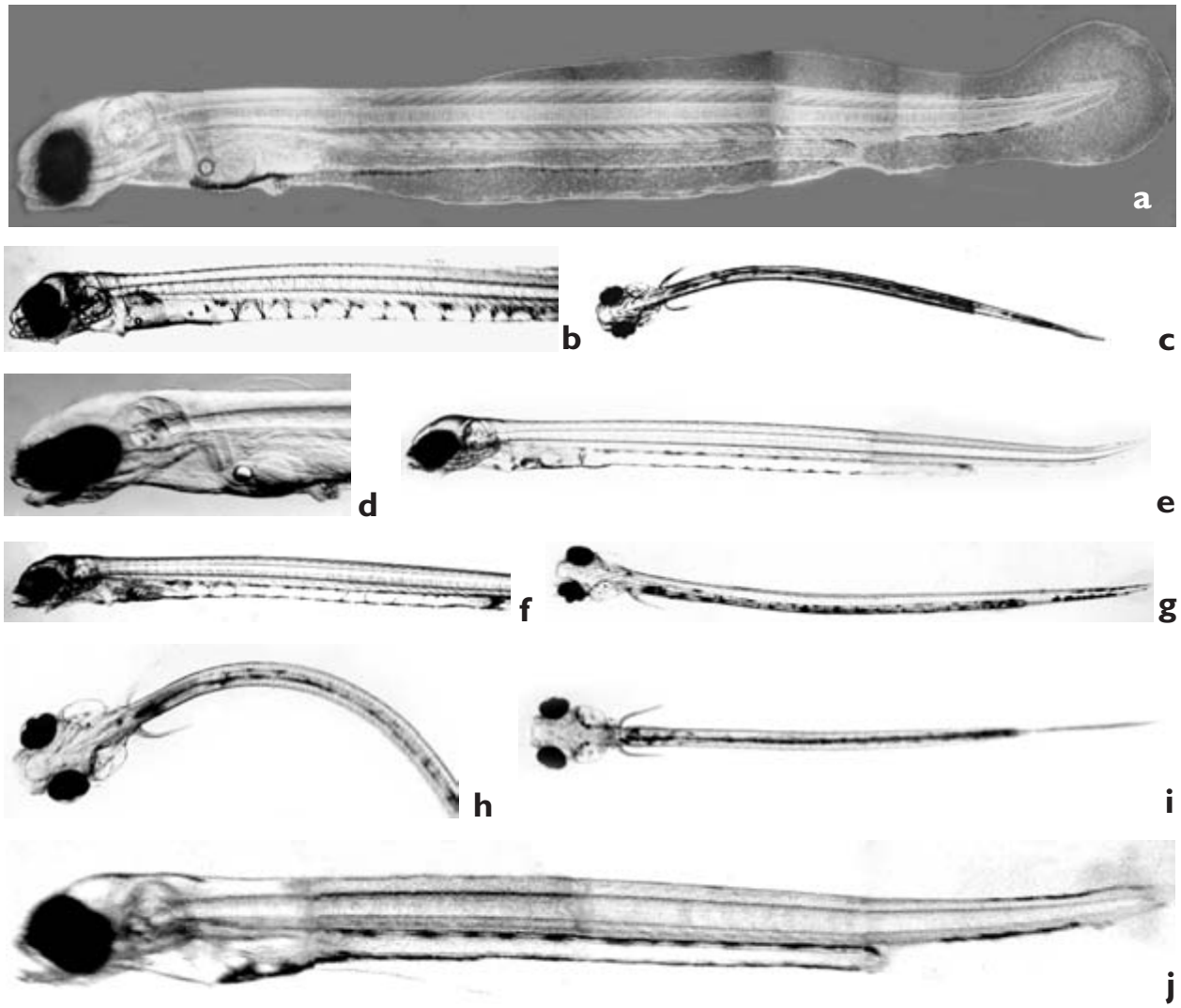

Figure 12. Postlarvae of *Galaxias rostratus.* Times given are after hatching (d = days, h= hours and m=minutes). a) Phase contrast microscopy 5d, b) 5d, c) 5d 5h 6m, d) 5d 12h, e) 6d 10h 26m, f) 7d 6h 21m, g) 7d 6h 36m, h) 10d 4h 54m, i) 11d 12h, j) 11d 12h.

Growth rates of the prolarvae were slower at this stage than they were later on (see Fig. 13). Movement of prolarvae up to this time was rarely observed. Activity had increased around the time of hatching, but shortly afterwards the prolarvae proceeded to lie on the substrate. At 5d the prolarvae were quite streamlined in side view, apart from the bulbous head. The yolk had all gone and only a single small oil globule remained. It was expected that this stage would be associated with the change from endogenous to exogenous feeding and the completion of prolarval development as in other species. This is a critical stage in larval development when high mortalities often occur (Toetz 1966) particularly if an adequate food source is delayed or is not present (Rowland 1992). However, in G. *rostratus* exogenous feeding was not observed until later. This may have been due to the artificial environment in which these larvae were kept.

Development of Post larvae

The dimensions of larvae at the commencement of the post larval stage at about 5d after hatching were as follows: length 7.4mm, oil globule diameter 0.28mm, eyes 0.39mm in diameter, lens 0.09mm in diameter, head width 0.77mm, depth at mid body 0.78mm, otic capsules 0.37 x 0.26mm. At this stage a second row of melanophores (approx. 15) started to develop above the previous row, below the vertebral column (Fig 12 b,e and f). This pigment was clearly visible dorsally also (Fig. 12 c), and a few chromatophores were dispersed amongst the melanopohores. Part of the buccal cavity and the intestinal tract could be seen at 5½d (Fig. 12 d). The large bulbous head was up to 0.92mm wide in some larvae (Fig. 12 g, h and i) at 7 - 11½d, with large eyes with protuberant lenses. Bony structures in the head such as jaw elements, branchial arches, otic capsules and otoliths, the spine, and large pectoral fins were clearly visible at this time. Pigment became increasingly prominent ventrally in the region where the stomach and anterior intestine were developing, as did the two longitudinal ventral lines of pigment (Fig. 12 j). Chromatophores also appeared dorsally in the caudal region of the tail (Fig. 12 j) and golden colouration occurred on the top of the head of some larvae. Some erosion of the fin fold commenced as indicated by its serrated edges.

From about 12d after hatching, larvae were far more active than before with a sinusoidal eel like wriggling action. As a result, they could only be photographed while curved (Fig. 14a-d). They seemed to swim without resting and often congregated near the water surface. Their movement through the water was relatively slow, but they were capable of rapid darts when disturbed. Around this time some fin rays first appeared in the dorsal and caudal region within the fin fold, which had serrated margins at the site of these rays. Although no feeding was actually observed, it is likely that exogenous feeding commenced during this period when activity increased.

Detailed development could not be followed beyond this stage because larvae could not be kept alive in the laboratory. In an attempt to provide a suitable exogenous food source for the larvae, feeding experiments were set up at this time with batches of recently hatched larvae using water from an aquaria (matured at least 3 months), green water from a pond and tap water. Approximately 50 larvae were placed in each of three 20L glass containers. All larvae had died by day 15 after hatching except those in green water which died in 18 days. No green material was present in the gut of these larvae. At 9 days most of these larvae were seen sitting on the bottom and mortalities increased rapidly after day 10. It is likely that a change from endogenous to exogenous feeding was occurring and the absence of suitable food caused these mortalities. Growth of larvae based on pond samples, however, supported the findings that the change from endogenous to exogenous feeding occurred at about day 15 and about 11mm in length. Growth rate seemed to increase after this time (Fig. 13). Larvae at around 30d old still had an enlarged head (Fig. 14e), but at around 60d (Fig. 14f and g) metamorphosis was complete, and they had adopted much of the form of a juvenile fish. The changes in form and the extensive increases in pigmentation that occur between 30 and 60d mark the approximate period during which the post-larval stage terminates and the juvenile stage commences. Hubbs (1943) defines the post-larval stage as "Larva following the time of absorption of yolk; applied only when the structure and form continues to be strikingly unlike that of the juvenile."

Abnormalities of various types were observed in some larvae as shown in Fig. 14h. Abnormal larvae had usually died by day 24.

The Juvenile

The juvenile stage started at around 40d after hatching, at an approximate length of 22mm. The total absence of scales in Galaxiidae makes the demarcation between post larvae and juvenile less clear than in other species.

In juveniles at 60d the fin folds had gone and all the fins were well developed (Fig. 14f and g), and although the body was somewhat transparent, it was slightly

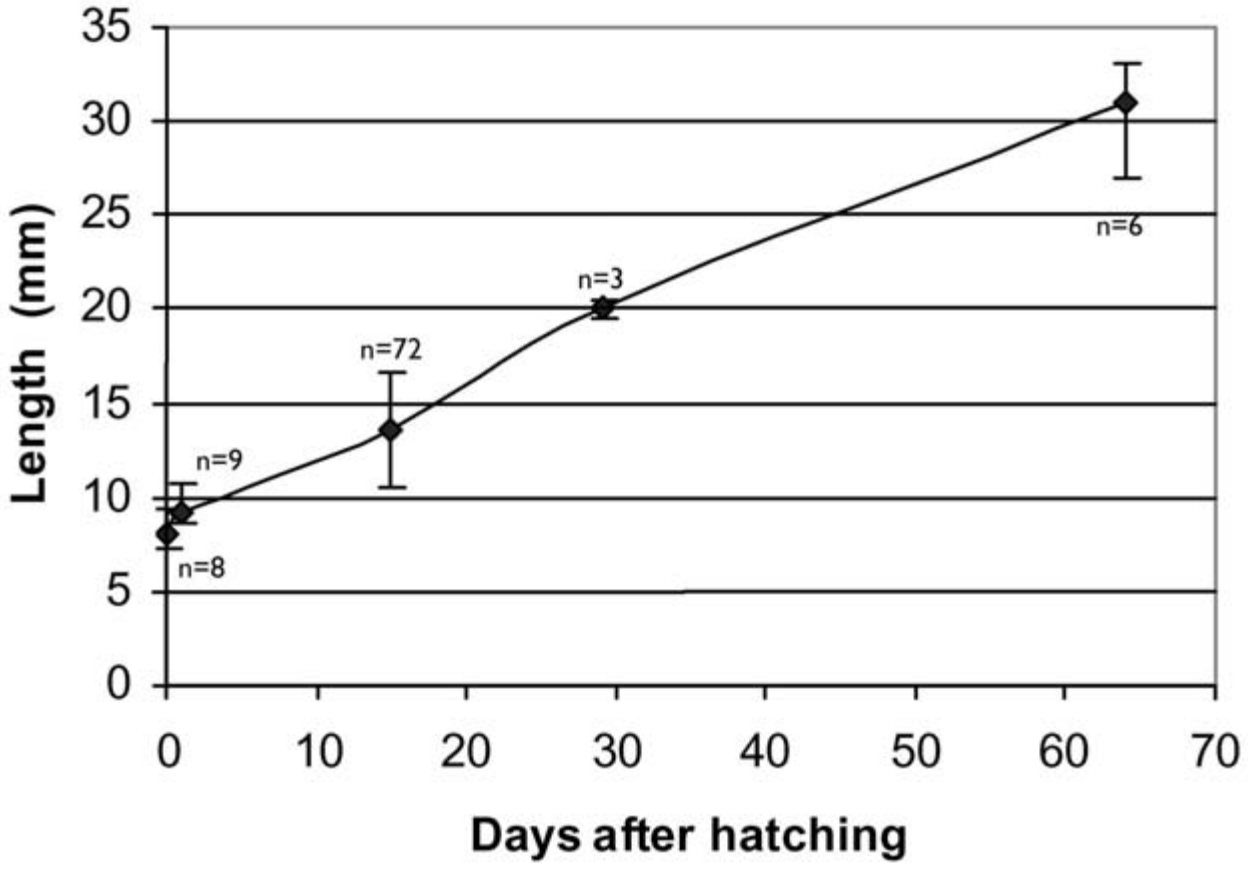

Figure 13. Growth in length of larvae of *Galaxias rostratus* after hatching based on pond samples (n= number in each sample). Bars represent range of lengths in each sample.

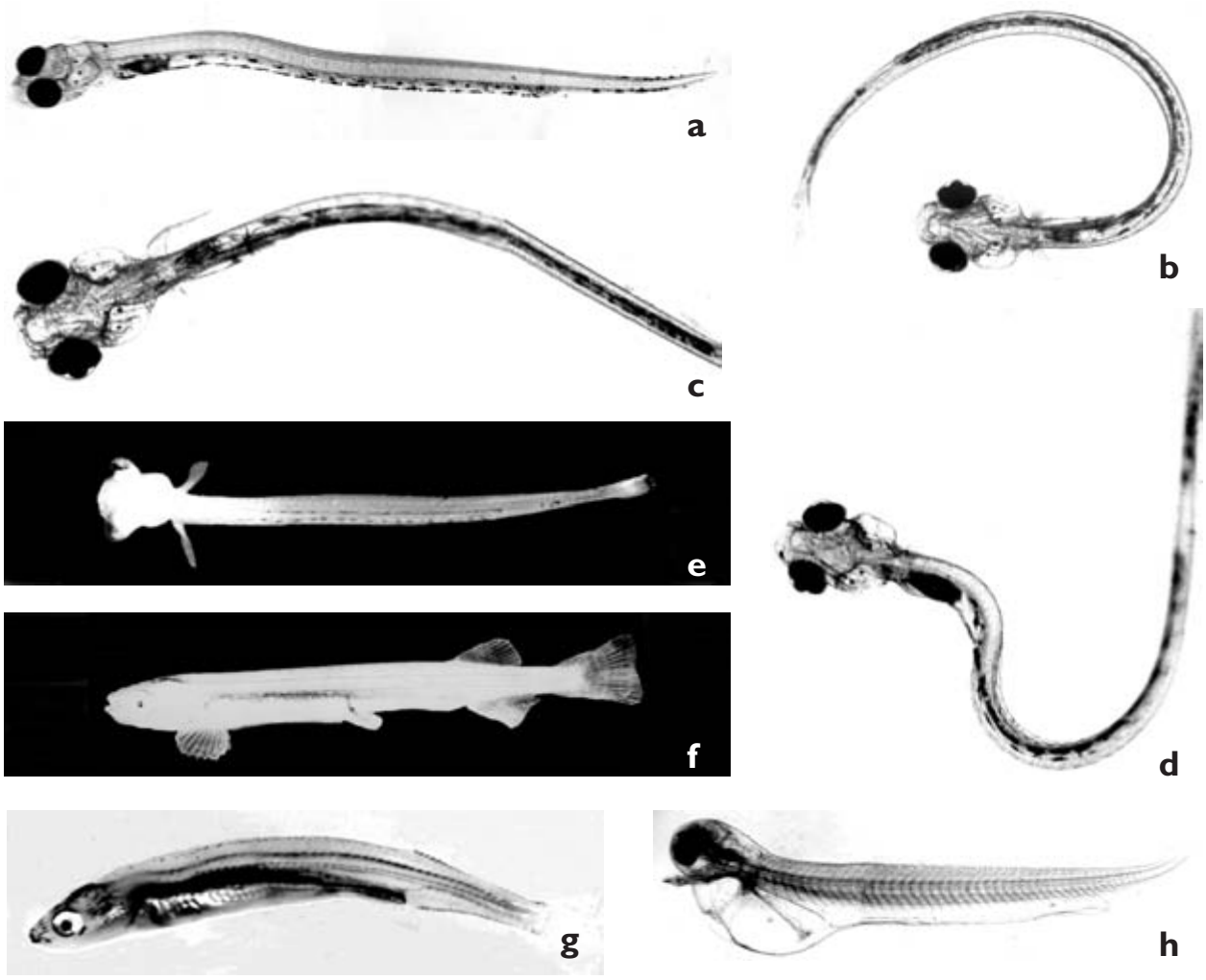

Figure 14. Postlarvae and juveniles of *Galaxias rostratus*. Times given are after hatching (d = days, h= hours and m=minutes). a) 12d 12h, b) 13d 2h 31m, c) 13d 2h 16m, d) 15d 19h 51m, e) approximately 35 d, f) approximately 60d, g) approximately 60d, h) 20d 4h deformed and has not grown.

yellowish along the back and caudal region and most of the abdominal cavity and head region were opaque. A marked line of pigment occurred along the dorsal edge of the vertebrae diminishing in size posteriorly, and the abdominal cavity was heavily pigmented (black) dorsally and along the intestine to the anus, while the ventral portion of the abdomen was silver, apart from some darker rib streaks in some fish. The large eyes had also turned silver apart from the black pupils. Fainter lines of pigment also occurred along the base of the dorsal and anal fins and patches of pigment were present on the top and sides of the head and around the snout.

The Adults

The largest *G. rostratus* examined had a total length of 15.0cm, caudal fork length of 14.6cm, and weighed 22.5g. This specimen was caught in Poison Waterhole Creek, Wagga Road. (Table 1), on 9 April 1970. It was a slightly gravid female with easily recognisable ovaries, but all ova were minute and it was not close to breeding. Males were generally smaller than females of the same age; the largest recorded being 11.15cm total length and 11.5g in weight. Adults generally have a greenish olive, to golden brown hue dorsally grading to a bright silvery white colour ventrally, which is an outer lining to the abdominal cavity (see Fig. 8c). Sometimes, but not always, the back and caudal region is rather transparent in appearance showing up a darker pigmented longitudinal mid body stripe following the dorsal portion of the abdominal cavity and vertebral column. Pigment spots are often present at the base of the fin rays. The eyes are a pronounced silver colour with a dark pupil. Fins are colourless. Some large fish, generally above 8.0 cm in length, have dark coloured but faint patches dorsally. Key characteristics of this species are the single dorsal fin, slightly protruding lower jaw and flattish top to the head.

The sex of large adult breeding fish can be easily distinguished as the breeding season approaches by observing the mid-vent region (Fig. 15 a, b and c). The urinogenital papilla of the female is a different shape to the male and the latter has a pinkish area covering its base. A transparent window runs anteriorly from the urinogenital papilla mid-ventrally facilitating examination of the testicular and ovarian tissue which is very different in appearance at this stage, because the larger ova can easily be seen.

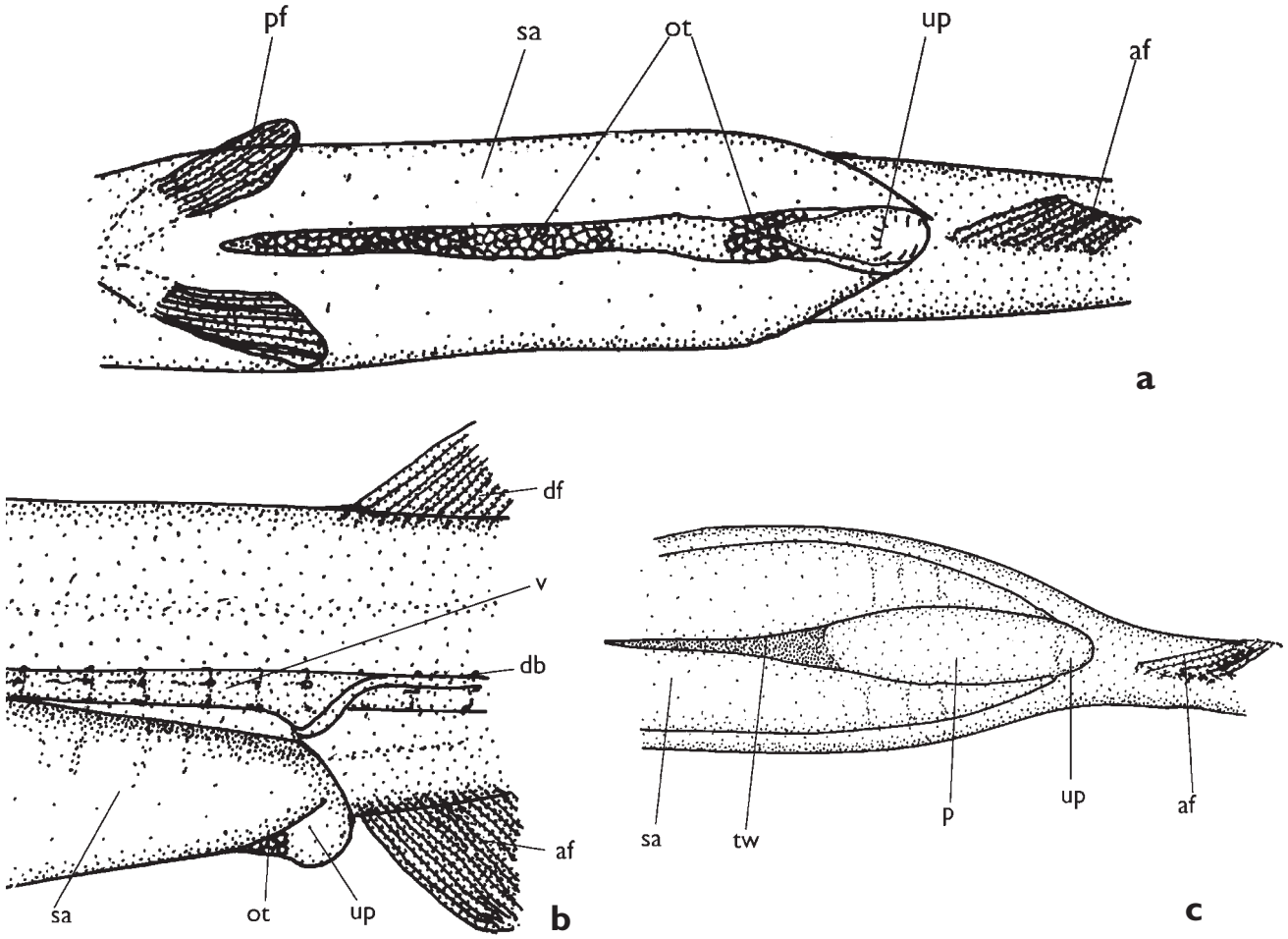

Figure 15. Urinogenital area of male and female *Galaxias rostratus* close to spawning. a) Ventral view of female. b) Lateral view of female. c) Ventral view of male. af anal fin; db dorsal blood vessel; df dorsal fin; ot ova visible through transparent window on abdomen; p pink area covering base of urinogenital papilla in male; pf pelvic fin; sa silver covering of abdomen; tw testes visible through transparent window on abdomen; up urinogenital papilla; v vertebra.

Fecundity

In fish examined, mature breeding males and females were above 93mm and 86mm in length and 5.5g and 4.7g in weight respectively.

Ovaries are white to yellowish in colour, paired, divided for their entire length and, when ripe, were unequal in length and weight and attain about 41% of the length of the fish. For example, in an 86mm long 4.7g fish the left ovary weighed 0.54g and was 35mm long while the right ovary weighed 0.46g and was 30mm long. The right lobe of the ovary was usually the largest and at times accounted for 70% of the total ovary weight.

The testes are whitish in colour and are divided also for their entire length. One testis is longer than the other. The testes may be very large, reaching up to 55% of the length of the fish. For example, in one fish 96mm long and weighing 7.0g, one testis weighed 1.08g and was 52mm long, while the other testis was 0.90g and 47mm long.

GSI in females ranged from 0.23 in early December, 12.38 in early May, to 37.37 by late July (Table 4). The highest GSI recorded was 40.02. The GSI fell markedly in mid September to 4.14 and down below 1.00 in late November indicating the breeding season was over by early September. Six fish collected in January 68 and four in March 68 had extremely small gonads suggesting the GSI was very low (Table 4).

The GSI of males (Table 5) showed a similar pattern being quite high in late April at 17.4 and peaking in June, July and August with a maximum GSI recorded of 31.2. The male GSI was too small to determine in early December. From these results, the GSI was much larger in females than in males at spawning.

Only seven adult females were checked for fecundity, with total egg counts varying between 2302 and 7004. The relative fecundity of five of these fish expressed as number of ova per gram body weight of fish varied from 279 to 1206 (Table 4). Thirteen fish between 52mm and 65mm were examined in December and January but the gonads were too small to find or identify. The indication, from the limited numbers available, is that number of eggs produced increased with increase in length and weight of fish, but relative fecundity declined with increase in fish size.

Table 4. Length, weight, fecundity and gonosomatic index of *Galaxias rostratus* arranged in order of calendar months. CF = caudal fork length. Relative fecundity is eggs per gram of body weight of fish.

FEMALES						
Month sampled	Length of fish mm	Weight of fish g	Ovary weight g	Fecundity	Relative fecundity eggs /g	Gono-somatic Index
April 70	150, CF 146	22.521	-	-	-	-
May 72	98	7.248	0.897	3311	457	12.38
May 68	87.8	3.318	(30mm long)	-	-	-
May 68	87	3.318	0.478	4000	1206	14.41
June 68	86	4.735	1.014	2302	486	21.42
June 68	86.8	4.735	1.014	-	-	21.42
July 69	136	19.000	7.100	7004	369	37.37
July 69	134.0	19.000	-	Eggs visible	-	-
Aug. 69	~115	decayed.	?	~ 5200	-	?
Aug. 69	~110	Pt decay	4.892	3740	-	?
Sept. 70	98	5.773	0.239	too small	-	4.140
Nov. 67	100	5.178	0.045	-	-	0.87
Dec. 67	62.0	1.129	-	-	-	-
Dec. 67	59.3	0.864	0.002	-	-	0.23
Dec. 67	60.2	0.914	Too small	-	-	-
?	134	17.790	7.120	4970	279	40.02
?	97	5.868	0.715	too small Imm.	-	12.18

16/1/68 6 pond fish collected for gonad development. No sex organs found therefore GSI approaching 0.

8/3/68 4 pond fish collected for gonad development. No sex organs found therefore GSI approaching 0.

Table 5. Length, weight and gonosomatic index of male *Galaxias rostratus* arranged in order of calendar months.

MALES				
Month sampled	Length of fish in mm	Weight of fish in g	Testes weight in g	Gonosomatic Index
April 72	105	6.977	1.215	17.41
May 72	103	7.179	1.230	17.13
May 68	77.5	2.232	(31mm long)	-
June 68	93	5.527	1.726	31.21
July 68	95.8	7.007	1.986	28.34
Aug. 69	111.5	11.500	2.700	23.48
Dec. 67	61.7	1.402	Too small	-
Dec. 67	63.5	1.234	Too small	-

Growth and length frequency

Length frequencies of G. *rostratus* sampled at Yanga Lake Regulator and at a swamp outlet to the Murrumbidgee River at Balranald (Table 1) in November 1968 are shown in Fig. 16. The samples contained fish of similar size (Yanga Lake : mean length 43.5mm, ± 5.7 SD, n = 127, and river outlet 45.0mm, ± 4.0 SD, n = 62).

Larvae in ponds grew from 6mm to nearly 30mm in 2 months from late August to late October (Figs 13, 17). It is likely, then, that the fish caught in late November at the two Balranald sites (Fig. 16) were young of the year.

The only food observed in the stomach of G. *rostratus* were Hemiptera (Corixiids) found in a 45 mm long fish caught in Willow Dam on 30 December 1968.

Cysts were found in the body musculature of a single fish caught by electro-shocking in Lake Talbot (Table 1), and cestodes were found in the gut cavity of fish caught at Willow Dam on 12 December 1967.

Discussion

The current paper provides some data on occurrence and catchability of G. *rostratus* over the 1964-1971 period. These data indicate a patchy distribution and difficulties in effectively sampling this species. Few G. *rostratus* were sampled in this period despite extensive sampling using a variety of techniques. Out of 32 intensive sampling efforts at Willow Dam, G. *rostratus* was caught on only 8 occasions. Furthermore in haul netting on hundreds of other occasions in dams, billabongs, lagoons and small

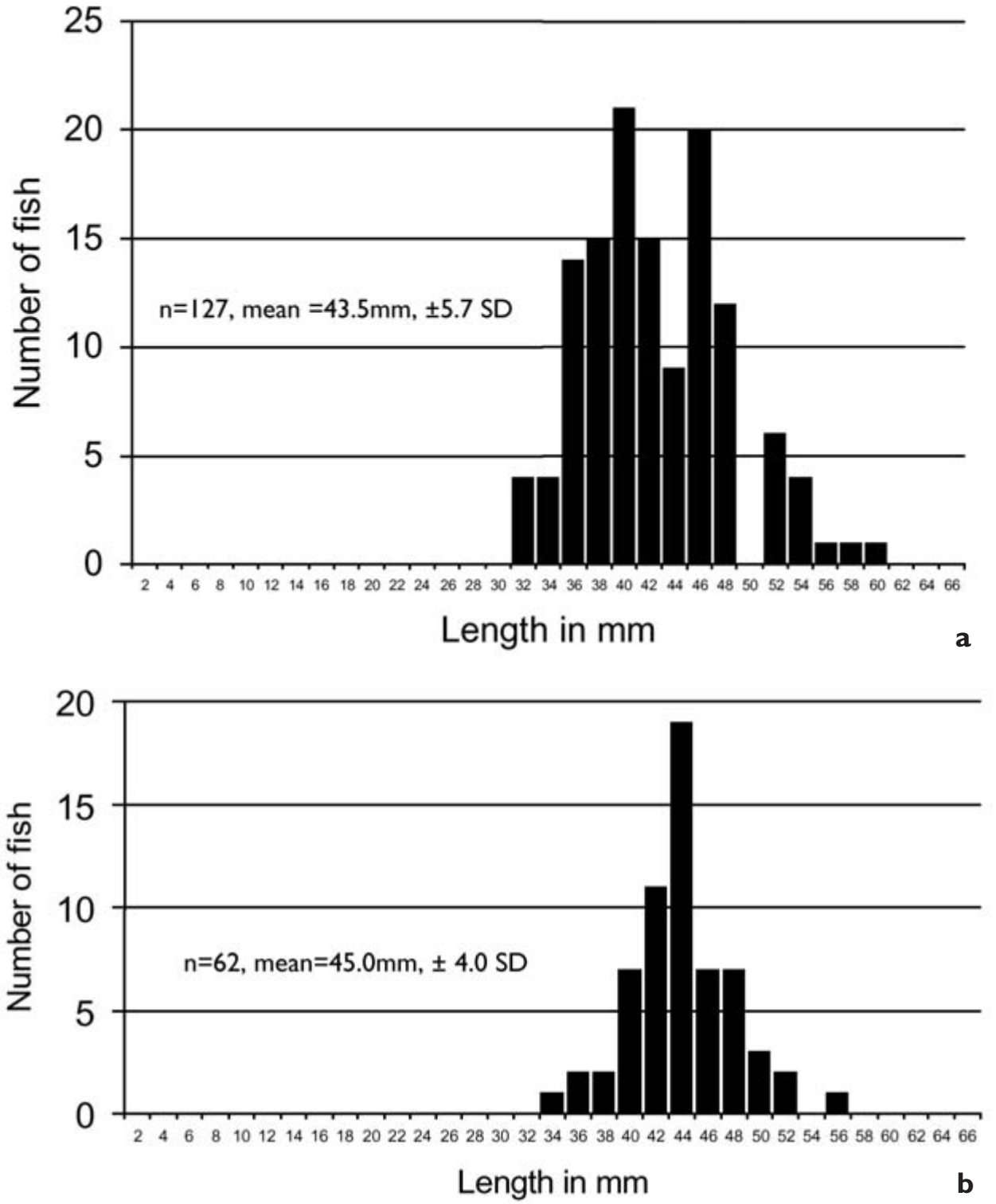

Figure 16. Length frequencies of *Galaxias rostratus* collected at a) Yanga Lake Regulator and b) swamp outlet to river near Balranald on 24 November 1968 (See Table 1). SD = Standard deviation.

creeks only on 8 additional occasions were they caught. Sampling technique influences catchability. On one occasion in Bartley's Dam (Table 1), *G. rostratus* could not be caught by haul netting although present in reasonable numbers, as they were seen jumping the net. They were eventually caught in bait traps baited with bread.

These data emphasise the dangers in drawing conclusions concerning the status of populations or species with respect to the Threatened Species Conservation Act (TSC Act 1995 (NSW Fisheries 2003)) based on one off, short term sampling programs, or by not considering the catchability of the fish, which may be highly variable (Llewellyn 1968).

G. rostratus is currently classified as Vulnerable by IUCN 2004 Red List, and the Australian Society of Fish Biology (ASFB Newsletter 2003 Vol 32 (2)). Morris *et al.* (2001) also recommend its status be elevated to vulnerable in NSW legislation and in the Commonwealth *Environment Protection*

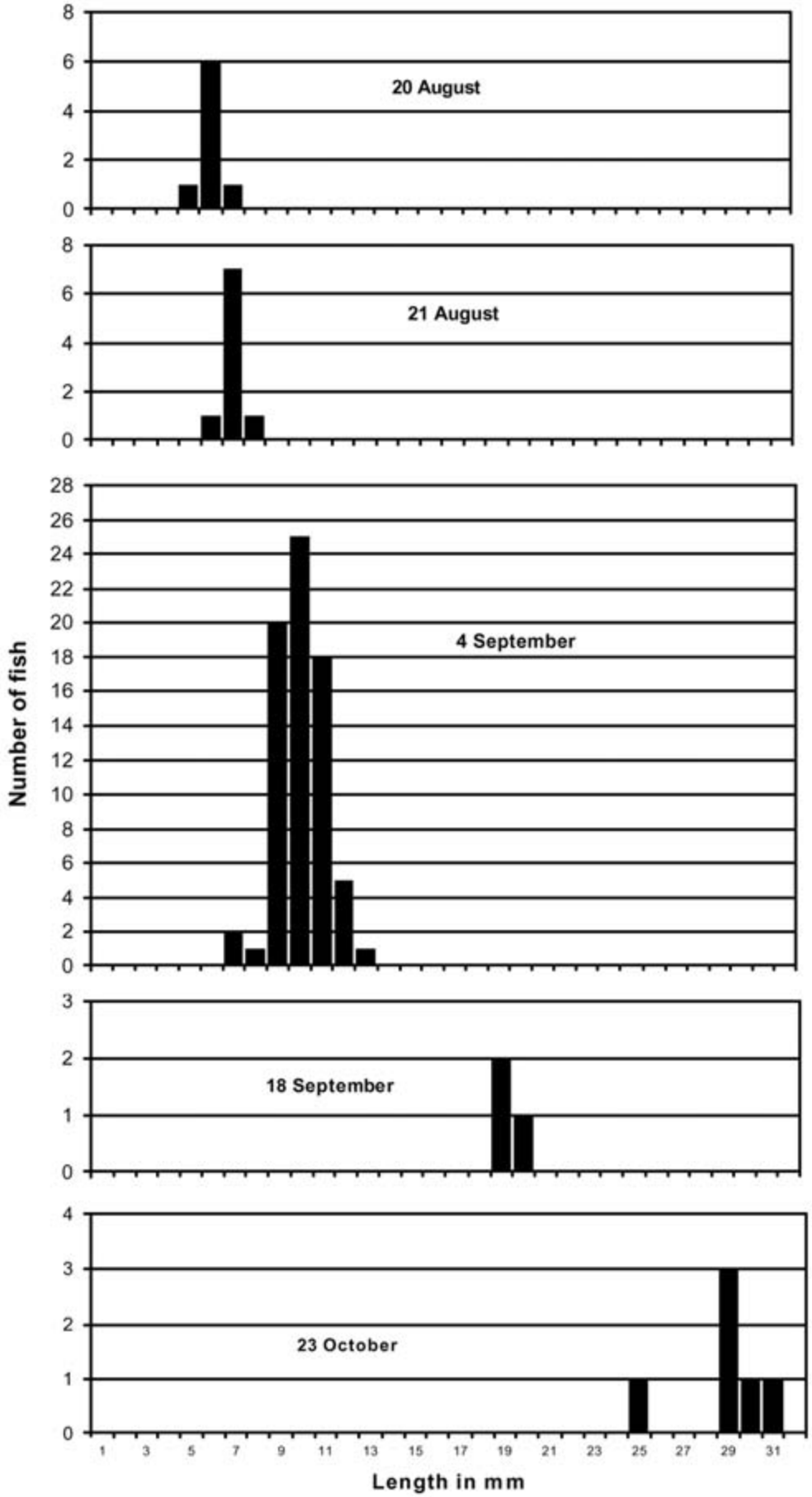

Figure 17. Length frequencies of larvae taken from breeding ponds at the research station between 20 August and 23 October 1968.

and Biodiversity Conservation Act (EPBC Act 1999). They state: "Distribution is now restricted and intermittent in the Murray region". This is certainly no different to its perceived status in the 1964-71 period. It is arguable whether it is appropriate to classify such species as endangered or vulnerable under the TSC Act 1995. These problems of categorisation under the TSC Act are likely to be relevant to most inland fish species. Fluctuations of Golden Perch *Macquaria ambigua,* based on recent improvements in angler catches and the recent sudden resurgence of Trout Cod *Maccullochella macquariensis,* emphasise the dangers involved in drawing conclusions as to the status of fish populations without looking at long term trends and having a better understanding of their biology and catchability. Other vertebrate populations too, for example kangaroos and waterfowl, fluctuate dramatically over long periods of time in this environment, often over five or ten year periods.

Thus it may not be appropriate to classify as threatened, populations that fluctuate in response to a flood and dry cycle, superimposed on seasonal temperatures, at a time when their numbers are low, because they have a natural ability to rebound when conditions improve.

To achieve conservation of fish communities in inland New South Wales, it may be more appropriate to channel limited funds into research to better understand the environmental requirements of inland fish species in general. It is likely that all species react in different ways to the same environmental conditions, and it is necessary to pay more attention to maintenance of conditions to benefit all species, than to earmark an individual species that may be inappropriately categorised, for specific attention.

The data presented here from the 1964-1971 period bring into question the classification suggested by Morris *et al.* 2001 for *G. rostratus* to be listed as vulnerable in the NSW TSC Act Schedule 2. If *G. rostratus* has to be categorised, "insufficient knowledge of populations and their dynamics" would be the most appropriate designation. Jackson (1993) proposed that it be categorised as "restricted" and Koehn and O'Connor (1990) that they be indeterminate. Wager and Jackson (1993) in the *Action Plan for Australian Freshwater Fishes* listed it as a rare species. In a comments section in this plan, P. Unmack advised that it "should be listed as indeterminate, small numbers known from a few localities, requires more survey work to determine status". This statement supports my earlier comments.

NSW Government has recently listed "*Aquatic ecological community* in the natural drainage of the lower Murray River catchment," and "….in the natural drainage system of the lowland catchment of the Darling River," as Endangered Ecological Communities. The defined area of the former community covers most of the range of *G. rostratus* which is included in the assemblage of species identified for that area. The latter community, as defined, occurs down stream of the only record of *G. rostratus* from this watershed and is not included in a list of species in that community. This general approach may provide better opportunities for addressing problems impacting on these communities rather than sometimes inappropriately earmarking individual species.

Very little information on the biology of *G. rostratus* has been published. A brief comment on a portion of the data presented in this paper (Llewellyn 1971) was the basis for the summary of the "Life History" of *G. rostratus* in the extensive review of the Galaxiidae by McDowall and Franknberg (1981). More recent reviews (Morris *et al.* 2001; Cadwallader and Backhouse 1983) have used this information, either attributing it to McDowall and Frankenberg (1981), or without citation.

The distribution of *G. rostratus,* supported by the findings in this study (Table 1), is restricted to the southern lower reaches of the Murray Darling (Plate 1), with only an isolated record from Rankins Lagoon near Bathurst in the Macquarie River catchment, which flows into the Darling River (McDowall and Fulton 1996; McDowall and Frankenberg 1981; Koehn and O'Connor 1990; Morris *et al.* 2001). It stretches from near Bathurst in the east to Goulburn River in the south and the Murray mouth in the west. It overlaps marginally with the Common Jollytail *Galaxias maculatus* and Climbing Galaxias *Galaxias brevipinnis* in the extreme lower reaches of the Murray River, with the latter species occasionally occurring in the higher reaches of the Murray, probably because it has crossed the divide through the Snowy Scheme (similar to eels which are also known versatile climbers). The overlap area with the Mountain Galaxias *Galaxias olidus* to the east lies in a north-south strip between Bathurst and Wagga Wagga.

The data presented in the current study suggest *G. rostratus* breeds from August to September. Of the seven *Galaxias* species occurring in the south eastern corner of mainland Australia, five breed for two months only between May and September (Koehn and O'Connor 1990; Pollard 1971; Llewellyn 1983; Chessman 1971; Williams 1975; Fulton 1986; Humphries 1986). The other two species are *G. maculatus* in which the estuarine population breeds from March to June and the landlocked form from July to October, and *G. olidus* which breed from June to November. No breeding of *Galaxias* sp. have been recorded in December, January and February in this area.

Based on size of mature fish 86mm, and rate of growth 6 to 30mm in two months and 45mm a month later, it seems likely some *G. rostratus* may spawn in their first year at around 80mm, but some particularly the larger fish (up to 150mm) are spawning in their second or third year. Further correlation between age and length, and confirmation of age at first spawning is required. This is nevertheless similar to the age of maturity of the freshwater form of *G. maculatus* according to Cadwallader and Backhouse (1983), in which some fish spawn in their first year but others may not spawn until their second or third year. *G. brevipnnis and G. truttaceus* probably do not breed until their second year (Williams 1975), while *G. olidus* do not breed until its third year (New South Wales Fisheries 1978). *Galaxiella pusilla,* on the other hand, breeds annually (McDowall 1980).

In *G. rostratus,* the only mature fish found were above 80mm. The largest found was 150mm in length and was likely to have been 2 or 3 years old. Cadwallader and Backhouse (1983) suggest *G. maculatus* as small as 55mm in length may be mature, while *G. cleaveri* was breeding at 80mm in length.

Induction of breeding in *G. rostratus* occurred on rising water temperatures and increasing photoperiod in late winter and

early spring when surface and bottom water temperatures rose above 10.5°C (fluctuating between 9 and 14°C). These cues are not the same as the cues identified for other *Galaxias* sp. *G. maculatus* bred on decreasing photoperiod in New Zealand (McDowall 1968) and in SE Australia in response to flood (Cadwallader and Backhouse 1983). Interestingly *G. truttaceus* bred on decreasing photoperiod and temperature in creeks and increasing photoperiod and temperature in lakes. *Galaxiella pusilla* bred at higher temperatures 16.0-21.0°C (Backhouse and Vanner 1978) than did other SE Australian Galaxiidae. Most other NSW inland fish are spring / summer breeders (Lake 1967a). Thus it appears that cues for breeding vary for different species and in different areas.

G. rostratus appears to scatter its eggs randomly when spawning. This differs from some other galaxiids in this region, for example *G. maculatus* spawns on flooded vegetation and the eggs hatch on reimmersion (Pollard 1971). *G. olidus* and *G. pusila* prefer to spawn under submerged leaves or leaf litter (Marshall 1989; Backhouse and Vanner 1978) and *G. truttaceus* among roots of emergent vegetation (Humphries 1987).

Observations and catches of *G. rostratus* suggest they school and move up stream in November and December, when they have been caught accumulating in numbers below weirs (Table 1 eg Willow Dam and the catches at two creek barriers at Balranald on 24 November 68). None of the fish caught at Willow Dam were gravid or even approaching breeding condition. Sampling was unsuccessful at other times of year at Willow Dam even though water was regularly flowing over the weir (Table 1). Upstream movement in *G. maculatus* and *G. olidus* (Pollard 1971; New South Wales Fisheries 1978) and downstream movement in *G. truttaceus* (Humphries 1987) appear to be associated with breeding. Movements associated with breeding have not been observed in *G. rostratus*, but it is worthy to note that breeding in ponds occurred when water was flowing through the ponds. There were no trials in static ponds.

It is uncertain whether *G. rostratus* die after spawning. However, heavy mortalities have been experienced in ponds around spawning time. When examining ponds many months after the breeding period, numbers of adult fish are often present with the juveniles. It is uncertain whether these fish have survived after breeding or whether they were non-breeders. Mortalities associated with spawning have been recorded in other Galaxiids. In *G. maculatus* many spent fish die after spawning (Pollard 1971). In the New Zealand *G. brevipinnis,* heavy pre-spawning mortalities have been experienced possibly due to delayed spawning from low water levels (Duffy 1996), and most die after spawning in *G. pusilla* as it is probably an annual species (Humphries 1986). Thus, the mortalities observed at spawning time in *G. rostratus* are consistent with observations of other Galaxiids.

Ova within the ovaries of *G. rostratus* seemed to develop simultaneously, most ova being at the same stage of development. This suggests there is a short spawning period. Examination of fish after the breeding season indicated that there were small numbers of large ova still remaining in the ovaries after breeding, and it is likely that these residual ova could be resorbed eventually. The high GSI, and hence very large energy reserves used in breeding, suggest that oneoff spawning over a short period occurs and adults may die at the conclusion of spawning. However some large fish died in ponds prior to breeding. The exact cause of death was not known.

The fertilised eggs of *G. rostratus* are compared with other SE Australian mainland Galaxiidae (Table 6). Fecundities are similar in *G. rostratus, G. maculatus, G. brevipinnis and G. truttaceus* all of which are higher than in *G. olidus and G. pusilla.* The diametres of all these Galaxiid eggs are between 1.0 and 2.0mm, while only *G. truttaceus* and *G. pusilla* are adhesive. The low fecundity (1888) and very small ova (0.56mm) reported for *G. rostratus* by Hume *et al.* (1983) suggest that the ova may not have been fully mature or the ovary may have been partly spent.

Incubation time to hatching in *G. rostratus* is shorter than other species. This is not surprising since it occupies the warmer waters of the state, and incubation time is known to be dependent on temperature in most species (Lagler *et al.* 1967; Edsal 1970). It is known also that incubation time may be dependent on other factors, eg on reimmersion in *G. maculatus* (Pollard 1971). Newly hatched larvae ranged between 5.7 and 9.5mm in most species except for *G. pusilla* which is smaller at 4.2-4.8mm.

There is no evidence to suggest *G. rostratus* can aestivate, although aestivation has been reported to occur in some other species such as *G. cleaveri* (Fulton 1986) and *G. pusilla* (McDowall and Fulton 1996). *G. rostratus* has been found in farm dams present in flood channels with high suspended clay with no vegetation, to billabongs, lagoons and weedy channels. Other species of Galaxiid have a strong affinity with weedy margins (*G. maculatus*) or with flowing streams and rocky pools (*G. brevipinnis* and *G. olidus*).

Table 6. Comparison of fecundity, fertilised eggs and larvae from mainland SE Australian Galaxiidae.

Galaxias species	Fecundity	Diameter (mm)	Description	Incubation time (days)	Just hatched larvae (mm)
G. rostratus[1]	2000-7000	1.3-1.6	Slightly adhesive	9	5.7-7.0
G. maculatus[2]	175-13500	1.2	Adhesive at first	14-56 flood dependent	6.6 (Mn)
G. olidus[2]	346-434	1.2-2.0	-	-	-
G. brevipinnis[2]	7500	1.3-1.6	amber	-	-
G. truttaceus[2]	5634	1.0 -1.3	Adhesive	28-42	6.5-9.5
G. cleaveri[2]	-	1.3-1.5	-	-	-
G. pusilla[2]	66-247	1.1-1.3	Adhesive	10-24	4.2-4.8

[1] This study. [2] Koehn and O'Connor (Review) (1990).

G. rostratus has been recorded in salinities up to 8.8 ppt (Chessman and Williams 1974). Other species, *G. truttaceus, G. cleaveri, G brevipinnis* and *G. maculatus* frequently enter sea water, and *G. maculatus* has been known to tolerate salinities up to 49 ppt (Frankenberg 1969).

Pond temperatures at the Inland Fisheries Research Station, Narrandera, occasionally reach extremes of 3.4 and 34.0°C while river temperatures at Balranald vary from 6.0 - 29.0°C (Llewellyn 1977). It is likely that *G. rostratus* can survive these ranges of temperatures. The maximum temperature at which other species have been reported to survive is 30.0°C in *G. olidus* (Fletcher 1979).

The eggs of *G. rostratus* can be differentiated from many other fish species by the large number and distribution of oil globules in the yolk, the diameter of the egg, slight adhesiveness of the chorion just after spawning, and the small perivitelline space. The type of egg and dispersive methods of spawning in *G. rostratus* is similar to that which occurs in the Spangled Perch *Leiopotherapon (Madigania) unicolor* (Llewellyn 1973), Southern Pygmy Perch *Nannoperca australis* (Llewellyn 1974), Murray Hardyhead *Craterocephaluis fluviatilis* (Llewellyn 1979) and the Australian Smelt *Retropinna semoni* (Milward 1965). In all these species, the eggs vary in size from 0.67mm in *L. unicolor* to 1.32mm in *C. fluviatilis*. These eggs have a small perivitelline space seen in early development generally about 9-14% of egg diameter when yolk is centrally placed. This small perivitelline space is characteristic of demersal eggs. These eggs are in contrast with the pelagic eggs of species like Golden Perch *Macquaria ambigua* and the Silver Perch *Bidyanus bidyanus* which have large perivitelline spaces (Lake 1967b) (about 30% of egg diameter is perivitelline space) when the yolk is centrally placed.

G. rostratus can be easily distinguished at the pro-larval stage by its length; position of the anus and number, location and size of the oil globules. In the pro-larval stage, key diagnostic features are the distribution of pigment, lack of obvious swim bladder and the apparent lack of cross muscle fibres on the myotomes along the body.

Differentiation of the larvae of *G. rostratus* from other species depends on some important features at different stages of development. Such features are size at hatching and at post-larval stage, distribution of pigment including size and time of pigmentation of the eye, the shape of gut (May and Gasaway 1967) including the position of the anus, body shape, position and location of the swim bladder if present, and number and location of the oil globules. Examination of some of the species occurring in inland NSW can be identified easily at prolarval stage using some of these characters (see Table 7). However the post larvae are somewhat more difficult to identify and a careful examination of shape, size and, in particular, the distribution of pigment as they grow is necessary to confirm identification.

Only two species, *R. semoni* and *G. rostratus*, have an anus position in the prolarva with a value above seven (see Table 7). However, the prolarval stage is complete in *R. semoni* by 5.29mm, whereas in *G. rostratus*, larvae at hatching are around 6.8mm. Species such as Freshwater Catfish *Tandanus tandanus* and Murray Cod *Maccullochella peelii peelii* have very small eyes. In the case of oil globules, the absence of obvious oil globules in *T. tandanus*, the dispersed oil globules in Southern Purple-spotted Gudgeon *Mogurnda adspersa* and very large oil globule in *M. ambigua* are good diagnostic features.

In conclusion, *G. rostratus* has a patchy distribution in inland New South Wales and unpredictable catchability. Its breeding biology is distinct from other species of inland fish, and the description of egg and larval development in this study should assist in identification of their early stages. Their breeding requirements will also help to formulate management strategies for inland waterways to ensure the survival of this and other species.

Table 7. Comparison of characters that distinguish the prolarvae of some inland fish species. Final length = length at end of prolarval stage when yolk is used up, anus position = length from tip of head to anus divided by total length times 10, eye a = days after hatching eye becomes pigmented (0 indicates eye pigmented at hatching), eye b = depth of eye divided by depth of head times 10. Prolarva stage days = length in days of prolarval stage.

PROLARVA (larva with yolk)							
SPECIES	Length at hatching mm	Final length mm	Anus position*	Oil globules	Eye		Prolarva stage days
					a	b	
Retropinna semoni [a]	4.61	5.29	7.2	Single anterior	0	4.5	2
Craterocephalus fluviatilis [b]	3.4	?	?	single	0	5.7	?
Nannoperca australis [c]	3.45	4.5	3.5	Several anterior	2.5d	4.4	10
Leiopotherapon unicolor [d]	2.18	4.5	3.7	1 medium posterior	2.2d	5.7	6
Macquaria ambigua [e]	3.2	6.5	4.8	1, ½ size of yolk	42hr	3.7	6
Bidyanus bidyanus [e]	3.6	6.8	4.2	1 posterior	2d	3.5	6
Hypseleotris klunzingeri [e]	1.9	3.0	4.3	1 small anterior	2	3.9	2
Tandanus tandanus [e]	7.2	13.0	4.4	none	2½ d	1.0	12½
Maccullochella peelii [e]	6.0 to 9.0	10.0	4.3	1 + few minute	8days	2.7	20
Mogurnda adspersa [f]	3.8	5.5	4.1	dispersed	0-2h	5.1	6¾
Melanotaenia fluviatilis [f]	4.0	2.5	3.3	Few small	0	5.3	2.5
Galaxias rostratus [f]	6.8	7.4	7.6	1 medium size anterior	0	5.0	5

[a] Milward 1965, [b] Llewellyn 1979, [c] Llewellyn 1974, [d] Llewellyn 1973, [e] Lake 1967b, [f] Llewellyn personal observations.

Acknowledgements

I wish to thank the New South Wales State Fisheries for support during this project. I should also like to thank Mr G Ralston and Mr H. Wood for their technical assistance and commitment during the research. Many thanks also go to Mr D. M. Smith and the late F.N. Atkinson field staff at the Inland Fisheries Research Station for assistance in collecting the fish and to Mr. A. F. Martin, Channel Attendant at Willow Dam for his helpful cooperation in manipulating water flows and allowing us to adjust them for short periods if necessary. Most importantly I should like to thank my partner Dr G.P. Courtice for her encouragement to complete this long overdue work and for her careful checking, editing and advice during the preparation of the manuscript.

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